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(54) Title: ISOLATION OF FIVE NOVEL GENES CODING FOR NEW Fc RECEPTORS-TYPE MELANOMA INVOLVED IN THE PATHOGENESIS OF LYMPHOMA/MELANOMA

(57) Abstract: This invention provides an isolated nucleic acid molecule which encodes immunoglobulin receptor, Immunoglobulin superfamily Receptor Translocation Associated, IRTA, protein. Provided too, are the IRTA proteins encoded by the isolated nucleic acid molecules, IRTA1, IRTA2, IRTA3, IRTA4 or IRTA5 proteins, having the amino acid sequences set forth in any of Figures 18A, 18B-1-18B-3, 18C-1-18C-2, 18D-1-18D-2 or 18E-1-18E-2. Oligonucleotides of the isolated nucleic acid molecules are provided. Antibodies directed to an epitope of a purified IRTA1, IRTA2, IRTA3, IRTA4 or IRTA5 proteins are also provided, as are pharmaceutical compositions comprising such antibodies or oligonucleotides. Methods for detecting a B cell malignancy in a sample from a subject; diagnosing B cell malignancy in a sample from a subject; detecting human IRTA protein in a sample; and treating a subject having a B cell cancer are also provided.

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ISOLATION OF FIVE NOVEL GENES
CODING FOR NEW Fc RECEPTORS-TYPE MELANOMA
INVOLVED IN THE PATHOGENESIS OF LYMPHOMA/MELANOMA

5 This application claims the priority of copending U.S. Provisional Application Serial No. 60/168,151, filed November 29, 1999, the contents of which are hereby incorporated by reference into the present application.

10 The invention disclosed was herein made in the course of work under NCI Grant No. CA 44029 from the National Cancer Institute. Accordingly, the U.S. Government has certain rights in this invention.

15 Throughout this application, various references are referred to in parentheses. Disclosures of these publication in their entirety are hereby incorporated by reference into this application to more fully describe the state of the art to which this invention pertains. Full
20 bibliographic citation for these references may be found at the end of this application, preceding the claims.

BACKGROUND OF THE INVENTION

25 Abnormalities of chromosome 1q21 are common in B cell malignancies, including B cell lymphoma and myeloma, but the genes targeted by these aberrations are largely unknown. By cloning the breakpoints of a t(1;14)(q21;q32) chromosomal translocation in a myeloma cell line, we have
30 identified two novel genes, *IRTA1* and *IRTA2*, encoding cell surface receptors with homologies to the Fc and Inhibitory

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Receptor families. Both genes are normally expressed in mature B cells, but with different distributions in peripheral lymphoid organs: IRTA1 is expressed in marginal zone B cells, while IRTA2 is also expressed in germinal center centrocytes and in immunoblasts. As the result of the t(1;14) translocation, the IRTA1 signal peptide is fused to the Immunoglobulin C α domain to produce a chimaeric IRTA1/C α fusion protein. In Multiple Myeloma and Burkitt lymphoma cell lines with 1q21 abnormalities, IRTA2 expression is deregulated. Thus, IRTA1 and IRTA2 are novel immunoreceptors with a potentially important role in B cell development and lymphomagenesis.

B-cell Non-Hodgkin's Lymphoma (B-NHL) and Multiple Myeloma (MM) represent a heterogeneous group of malignancies derived from mature B cells with phenotypes corresponding to pre-Germinal Center (GC) (mantle cell), GC (follicular, diffuse large cell, Burkitt's), or post-GC B cells (MM) (for review, Gaidano and Dalla-Favera, 1997; Kuppers et al., 1999). Insights into the pathogenesis of these malignancies have been gained by the identification of recurrent clonal chromosomal abnormalities characteristic for specific disease subtypes. The common consequence of these translocations is the transcriptional deregulation of protooncogenes by their juxtaposition to heterologous transcriptional regulatory elements located in the partner chromosome (Gaidano and Dalla-Favera, 1997). These heterologous transcriptional regulatory elements can be derived from the Immunoglobulin (IG) locus or from other partner chromosomal loci. Examples include MYC in t(8;14)(q24;q32) in Burkitt's lymphoma (BL) (Dalla-Favera et al., 1982; Taub et al., 1982), the CCND1 gene

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deregulated by the t(11;14)(q13;q32) in mantle cell lymphoma (MCL) (Rosenberg et al., 1991) and multiple myeloma (MM) (Ronchetti et al., 1999), *BCL2* involved in the t(14;18)(q32;q21) in follicular lymphoma (FL) (Bakhshi
5 et al., 1985), *BCL6* in t(3;14)(q27;q32) in diffuse large B cell lymphoma (DLCL) (Ye et al., 1993), as well as *FGFR3* in t(4;14)(p16;q32) (Chesi et al., 1997), *MAF* in t(14;16)(q32;q23) (Chesi et al., 1998) and *MUM1/IRF4* in
10 t(6;14)(p25;q32) (Iida et al., 1997) in multiple myeloma (MM). The identification of these oncogenes has offered valuable insights into the pathogenesis and diagnosis of their corresponding malignancies.

Chromosomal abnormalities involving band 1q21-q23 are
15 among the most frequent genetic lesions in both B-NHL and MM. Among NHL subtypes, translocation breakpoints at 1q21-q23, including translocations and duplications, have been reported, often as the single chromosomal abnormality, in 17-20% of follicular and diffuse large B-
20 cell lymphoma (DLCL), in 39% of marginal-zone B cell lymphoma (Offit et al., 1991; Whang-Peng et al., 1995; Cigudosa et al., 1999) and in 27-38% of Burkitt lymphoma, where they represent the second most common cytogenetic abnormality after translocations involving the *MYC* proto-
25 oncogene (Berger and Bernheim, 1985; Kornblau et al., 1991). Comparative genome hybridization (CGH) has also identified 1q21-q23 as a recurring site for high-level amplification in 10% of DLCL cases (Rao et al., 1998). In
30 MM, trisomy of the 1q21-q32 region has been reported in 20-31% of cases (Sawyer et al., 1995), amplification of the 1q12-qter region in 80% of cell lines and 40% of primary tumors (Avet-Loiseau et al., 1997), and nonrandom

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unbalanced whole-arm translocations of 1q, associated with the multiduplication of the adjacent 1q21-22 region, were found in 23% of patients with abnormal karyotypes (Sawyer et al., 1998).

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The high frequency of involvement of 1q21 structural rearrangements in B-cell malignancies suggests that this locus may harbor genes critical to the pathogenesis of these diseases. Cloning of a t(1;14)(q21;q32) in a pre-B
10 cell acute lymphoblastic leukemia cell line previously identified a novel gene, *BCL9* deregulated in this single case (Willis et al., 1998), but not involved in other cases. A recent report characterized the t(1;22)(q22;q11) in a follicular lymphoma (FL) cell line and found that the
15 *FCGR2B* locus, encoding the low affinity IgG Fc receptor FCGR1B, was targeted in this cell line and in two additional FL cases (Callanan et al., 2000). Finally, the *MUC1* locus has been identified in proximity of the breakpoint of a t(1;14)(q21;q32) in NHL (Dyomin et al.,
20 2000; Gilles et al., 2000), and *MUC1* locus rearrangements have been found in 6% of NHL with 1q21 abnormalities (Dyomin et al., 2000). These results highlight the heterogeneity of the 1q21 breakpoints and the need to identify additional candidate oncogenes situated in this
25 locus, since the large majority of these alterations remain unexplained.

The aim of this study was to further explore the architecture of 1q21 chromosomal rearrangements in B cell
30 malignancy. To that end, we have employed a molecular cloning approach of the t(1;14)(q21;q32) present in the myeloma cell line FR4. We have identified two novel genes

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that are differentially targeted by 1q21 abnormalities. These genes code for five novel members of the immunoglobulin receptor family, *IRTA1*, *IRTA2*, *IRTA3*, *IRTA4* and *IRTA5* (Immunoglobulin superfamily Receptor Translocation Associated genes 1, 2, 3, 4, and 5), which may be important for normal lymphocyte function and B cell malignancy.

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SUMMARY OF THE INVENTION

This invention provides an isolated nucleic acid molecule which encodes immunoglobulin receptor, Immunoglobulin superfamily Receptor Translocation Associated, IRTA, protein.

This invention provides a method of producing an IRTA polypeptide (protein) which comprises: (a) introducing a vector comprising an isolated nucleic acid which encodes an immunoglobulin receptor, Immunoglobulin superfamily Receptor Translocation Associated, IRTA, protein into a suitable host cell; and (b) culturing the resulting cell so as to produce the polypeptide.

This invention provides an isolated nucleic acid molecule comprising at least 15 contiguous nucleotides capable of specifically hybridizing with a unique sequence included within the sequence of the isolated nucleic acid molecule encoding IRTA protein. In an embodiment, the IRTA protein may be IRTA1, IRTA2, IRTA3, IRTA4 or IRTA5 protein, or fragment(s) thereof, having the amino acid sequence set forth in any of Figures 18A, 18B-1-18B-3, 18C-1-18C-2, 18D-1-18D-2 or 18E-1-18E-2, respectively.

This invention provides a method for detecting a B cell malignancy or a type of B cell malignancy in a sample from a subject wherein the B cell malignancy comprises a 1q21 chromosomal rearrangement which comprises: a) obtaining RNA from the sample from the subject; b) contacting the RNA of step (a) with a nucleic acid molecule of at least 15 contiguous nucleotides capable of specifically

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hybridizing with a unique sequence included within the sequence of an isolated RNA encoding human IRTA protein selected from the group consisting of human IRTA1, IRTA2, IRTA3, IRTA4 and IRTA5, under conditions permitting
5 hybridization of the RNA of step (a) with the nucleic acid molecule capable of specifically hybridizing with a unique sequence included within the sequence of an isolated RNA encoding human IRTA protein, wherein the nucleic acid molecule is labeled with a detectable marker; and c)
10 detecting any hybridization in step (b), wherein detection of hybridization indicates presence of B cell malignancy or a type of B cell malignancy in the sample.

This invention provides an antisense oligonucleotide
15 having a sequence capable of specifically hybridizing to an mRNA molecule encoding a human IRTA protein so as to prevent overexpression of the mRNA molecule.

This invention provides a purified IRTA1 protein
20 comprising the amino acid sequence set forth in Figure 18A (SEQ ID NO:1).

This invention provides a purified IRTA2 protein comprising the amino acid sequence set forth in Figures
25 18B-1-18B-3 (SEQ ID NO:3).

This invention provides a purified IRTA3 protein comprising the amino acid sequence set forth in Figures
18C-1-18C-2 (SEQ ID NO:5).

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This invention provides a purified IRTA4 protein comprising the amino acid sequence set forth in Figures 18D-1-18D-2 (SEQ ID NO: 7).

- 5 This invention provides a purified IRTA5 protein comprising the amino acid sequence set forth in Figures 18E-1-18E-2 (SEQ ID NO: 9).

This invention provides an antibody/antibodies directed to
10 an epitope of a purified IRTA1, IRTA2, IRTA3, IRTA4 or IRTA5 protein, or fragment(s) thereof, having the amino acid sequence set forth in any of Figures 18A, 18B-1-18B-3, 18C-1-18C-2, 18D-1-18D-2 or 18E-1-18E-2.

- 15 This invention provides an antibody directed to a purified IRTA protein selected from the group consisting of IRTA1, IRTA2, IRTA3, IRTA4 and IRTA5.

This invention provides a pharmaceutical composition
20 comprising an amount of the antibody directed to an IRTA protein effective to bind to cancer cells expressing an IRTA protein selected from the group consisting of human IRTA1, IRTA2, IRTA3, IRTA4 and IRTA5 so as to prevent growth of the cancer cells and a pharmaceutically
25 acceptable carrier.

This invention provides a pharmaceutical composition comprising an amount of any of the oligonucleotides of nucleic acid molecules encoding IRTA proteins described
30 herein effective to prevent overexpression of a human IRTA protein and a pharmaceutically acceptable carrier capable.

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This invention provides a method of diagnosing B cell malignancy which comprises a 1q21 chromosomal rearrangement in a sample from a subject which comprises:

5 a) obtaining the sample from the subject; b) contacting the sample of step (a) with an antibody directed to a purified IRTA protein capable of specifically binding with a human IRTA protein selected from the group consisting of human IRTA1, IRTA2, IRTA3, IRTA4 and IRTA5 IRTA protein on a cell surface of a cancer cell under conditions

10 permitting binding of the antibody with human IRTA protein on the cell surface of the cancer cell, wherein the antibody is labeled with a detectable marker; and c) detecting any binding in step (b), wherein detection of binding indicates a diagnosis of B cell malignancy in the

15 sample.

This invention provides a method of detecting human IRTA protein in a sample which comprises: a) contacting the sample with any of any of the above-described anti-IRTA

20 antibodies under conditions permitting the formation of a complex between the antibody and the IRTA in the sample; and b) detecting the complex formed in step (a), thereby detecting the presence of human IRTA in the sample.

25 This invention provides a method of treating a subject having a B cell cancer which comprises administering to the subject an amount of anti-IRTA antibody effective to bind to cancer cells expressing an IRTA protein so as to prevent growth of the cancer cells and a pharmaceutically

30 acceptable carrier, thereby treating the subject.

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This invention provides a method of treating a subject having a B cell cancer which comprises administering to the subject an amount of an antisense oligonucleotide having a sequence capable of specifically hybridizing to
5 an mRNA molecule encoding a human IRTA protein so as to prevent overexpression of the human IRTA protein, so as to arrest cell growth or induce cell death of cancer cells expressing IRTA protein(s) and a pharmaceutically acceptable carrier, thereby treating the subject.

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The invention also provides a pharmaceutical composition comprising either an effective amount of any of the oligonucleotides described herein and a pharmaceutically acceptable carrier.

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The invention also provides a pharmaceutical composition comprising either an effective amount of an antibody directed against an epitope of any IRTA protein described herein and a pharmaceutically acceptable carrier.

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BRIEF DESCRIPTION OF THE FIGURES

Figures 1A-1B. Molecular cloning of the translocation $t(1;14)(q21;q32)$ in the FR4 multiple myeloma cell line. Fig. 1A) Schematic representation of the λ FR4B-5 and λ FR4S-a clones, representing der(14) and der(1) breakpoints, and of the germline IgH and 1q21 loci. Fig. 1B) Nucleotide sequence of the breakpoint junction and its alignment to the corresponding germline regions of chromosome 14. S α , IgA switch region; LCR: 3' IgH locus control region; B, *Bam*HI; H, *Hind*III; X, *Xho*I.

Figures 2A-2B. Genomic map of the 1q21 locus in the vicinity of the FR4 breakpoint. Fig. 2A) Restriction endonuclease map and schematic representation of genomic clones, i.e. bacteriophages (1), P1 artificial chromosomes (PACs) (2), and yeast artificial chromosome (YAC) (3), spanning the germline 1q21 locus at the FR4 breakpoint region (arrowhead). The name of each clone is placed directly on top of its representation. End fragments derived from the PAC and YAC inserts are depicted as circles, with either an SP6/T7 vector orientation (PAC), or left/right arm vector orientation (YAC). The top panel in Fig. 1A depicts the genomic organization of two genes surrounding the FR4 breakpoint. The

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two genes were identified by exon trapping of PAC 49A16. They are closely spaced in the genome, within ≤ 30 Kb of each other and are named MUM2 and MUM3 (multiple myeloma-2 and 3). In the scheme of their genomic loci, black boxes indicate coding exons, whereas white and light or medium grey boxes indicate non-coding exons. Connecting introns are lines. MUM3 (left) gives rise to three alternatively spliced mRNAs, all sharing a common 5' untranslated region (UTR) but diverse 3' UTRs (marked by different shades). Numbers underneath the boxes identify the order of exons in the cDNA. Exons less than 100 bp are depicted as thin vertical lines. The position and size of each exon was determined by sequencing of genomic PAC and phage clones and by hybridization of cDNA probes to endonuclease-digested clone DNA. PAC and YAC mapping was performed by partial digestion with rare cutting enzymes followed by Pulse-Field-Gel-Electrophoresis and hybridization to internal and end-derived probes. Dashed lines align regions of overlap. S, SacI; H, HindIII; S, SmaI; P, PmeI; Fig. 2B) Genethon genetic linkage map of 1q21 in the region of the MUM2/MUM3 locus. Sequence-tagged sites (STS) are ordered in approximate distance previously determined by Dib, C., et al. (1996) Nature, 380:162-

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164. STS WI-5435 (in bold) is contained within YAC 23GC4 and PAC 49A16. Parallel vertical lines represent interrupted segments, whose approximate size is depicted above in megabases (MB). Sizing was estimated by the size of nonchimeric YAC contigs between two markers. The BCL9 gene at the centromere was cloned from a different t(1;14)(q21;q32) breakpoint by Willis T.G. et al., (1998) Blood 91, 6:1873-1881. The FcGRIIA gene is at the 1q21-q22 chromosomal band border.

Figures 3A-3C. MUM2 mRNA structure and expression pattern.

Fig. 3A) Schematic representation of MUM2 mRNA. Pattern-filled, wide boxes represent coding domains and narrow empty boxes represent untranslated regions. SP, signal peptide; EC, extracellular domain; TM, transmembrane domain; CYT, cytoplasmic domain; A(n), polyA tail. The extracellular region is composed of four immunoglobulin-like domains as depicted. Alternative polyadenylation signals (arrows) generate three MUM2 mRNA species (a, b, c) whose length (in Kb) ranges from 2.6-3.5. Fig. 3B) Northern blot analysis of MUM2 mRNA expression in human tissues of the immune system. The cDNA probe used for the analysis is shown as a solid bar underneath the mRNA scheme in Fig. 3A). Each lane contains 2 μ g mRNA of the

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corresponding tissue. On the right side of the blot, the position of RNA molecular weight markers is depicted. The position of MUM2 and GAPDH mRNA transcripts is shown by arrows. (A GAPDH probe was included in the hybridization as an internal control - 0.15 ng labelled +50 ng unlabelled probe-). The results of this analysis show weak expression of MUM2 in lymph node and spleen. MUM2 expression was not detected in a variety of other human tissues (data not shown). Fig. 3C) Northern blot analysis of MUM2 expression in total RNA from EREB, a conditional EBV-transformed B lymphoblastoid cell line. EREB carries the EBV genome with an EBNA2-estrogen receptor fusion protein, active only in the presence of estrogen. For this experiment, cells were grown in the presence of estrogen (1µg/ml), followed by estrogen withdrawal for the indicated times. Upon estrogen withdrawal, EREB cells undergo G0/G1 arrest, determined by the loss of c-myc expression. In Fig. 3C, a Northern blot of EREB total RNA (10µg per lane) was hybridized with the MUM2 cDNA probe shown in Fig. 3A and the GAPDH internal control probe, as in Fig. 3B. Arrows indicate the position of the corresponding mRNAs on the EREB blot. a, band c correspond to the MUM2 species in panel Fig 3A. The same blot was then stripped and reprobbed with a

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c-myc cDNA probe (exon 2) to verify cellular G0/G1 arrest. Quantitation of MUM2 mRNA by the use of a phosphorimager densitometric analysis demonstrates a 10-fold increase in their levels within 48 hrs of estrogen withdrawal, suggesting that MUM2 expression is elevated as the cells enter a resting phase.

10 **Figures 4A-4B.** MUM3 mRNA structure and expression pattern. Fig. 4A) Schematic representation of MUM3 mRNA. Pattern-filled, wide boxes represent coding domains and narrow empty or gray boxes represent untranslated regions. SP, signal peptide; EC, extracellular domain; TM, transmembrane domain; CYT, cytoplasmic domain; A(n), polyA tail. The extracellular region is composed of immunoglobulin-like domains, as depicted.

15 Alternative splicing generates four mRNA species with diverse subcellular localization. MUM3-a and -d proteins are secreted, whereas MUM3-b contains a hydrophobic stretch of amino acids at its C-terminus which may serve as a signal for addition of a glycosylphosphatidyl-inositol anchor (GPI-anchor), as shown. MUM3-c spans the plasma membrane. Sequence identity among species is indicated by identical filling. Fig. 4B) Northern blot analysis of MUM3 mRNA expression in multiple human tissues (left) and in

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5 various lymphoid and non-lymphoid cell lines (right). The cDNA probe used is shown as a solid bar below the cDNA scheme in Fig. 4A. Each lane contains 2 μ g mRNA of the corresponding tissue or cell line. The position of MUM3 and GAPDH mRNA transcripts is shown by arrows. (A GAPDH probe was included in the hybridization as an internal control as described in Fig. 3)

10 a, b, c and d correspond to the MUM3 mRNA species shown in Fig. 4A. RD, NC42 and CB33, Epstein-Barr virus transformed B lymphoblastoid cell lines; EREB, conditional EBV-transformed B

15 lymphoblastoid cell line; FR4, plasma cell line; MOLT4 and HUT78, T cell lines; HL60 and U937, myelomonocytic cell lines; K562, erythroid cell line. The results suggest that MUM3 is expressed solely in the immune system tissues of bone marrow, lymph and spleen and in particular in B cells with a lymphoblastoid phenotype.

20

25 **Figure 5.** Nucleotide and amino acid sequence of human MUM2. The deduced amino acid sequence is shown above the nucleotide sequence in one-letter code and is numbered on the right, with position 1 set to the first codon of the signal peptide. The predicted signal peptidase site was derived by a computer algorithm described in Nielsen et al., Protein Engineering 10, 1-6 (1997) and is

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marked by an arrowhead. The polyadenylation signal AATAAA is underlined. Potential sites for N-glycosylation are also underlined in the amino acid sequence. A hydrophobic stretch of 16 amino acids predicted to span the plasma membrane is doubly underlined. Consensus SH2-binding sites are highlighted by a wavy underline.

Figure 6A.

Nucleotide and amino acid sequence of human MUM3-a. The deduced amino acid sequence is shown above the nucleotide sequence in one-letter code and is numbered on the right, with position 1 set to the first codon of the signal peptide. The predicted site for signal peptidase cleavage was derived as previously stated above and is marked by an arrowhead. The polyadenylation signal ATTAAA is underlined. Potential sites for N-glycosylation are also underlined in the amino acid sequence. The protein lacks a transmembrane domain and is predicted to be secreted.

Figure 6B.

Nucleotide and amino acid sequence of human MUM3-b. The deduced amino acid sequence is shown above the nucleotide sequence in one-letter code and is numbered on the right, with position 1 set to the first codon of the signal peptide. The predicted site for signal peptidase cleavage was derived as

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previously stated above and is marked by an arrowhead. The polyadenylation signal AATAAA is underlined. Potential sites for N-glycosylation are underlined in the amino acid sequence.

Figure 6C-1-6C-2. Nucleotide and amino acid sequence of human MUM3-c. The deduced amino acid sequence is shown above the nucleotide sequence in one-letter code and is numbered on the right, with position 1 set to the first codon of the signal peptide. The predicted site for signal peptidase cleavage was derived as previously stated above and is marked by an arrowhead. The polyadenylation signal AATAAA is underlined. Potential sites for N-glycosylation are underlined in the amino acid sequence. A hydrophobic stretch of 23 amino acids predicted to span the plasma membrane is doubly underlined. Consensus SH2-binding sites are highlighted by a wavy underline.

Figures 7A-7C. t(1;14)(q21;32) in FR4 generates a MUM2/Ca fusion transcript. Fig. 7A) Schematic representation of the der(14) genomic clone λ FR4B-5 and of the germline IgHA1 locus. The FR4 breakpoint is marked by an arrow. Filled and open boxes represent the

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MUM2 and Calpha coding and non-coding exons respectively. The position of the MUM2 exon 1 probe used for Northern blot analysis is shown by a bar. Fig. 7B) Northern blot analysis with a MUM2 exon 1 probe on FR4 and additional cell lines detects an abnormal message of 0.8 Kb, selectively in FR4. Arrowheads point to the location of normal MUM2 message in EREB mRNA. JJN3 and U266, myeloma cell lines; EREB, conditional EBV-transformed B lymphoblastoid cell line. Two μ g of polyA+ RNA were loaded per lane. Fig. 7C) Nucleotide and amino acid sequence of the MUM2-Ca fusion cDNA in FR4. The cDNA was amplified by RT-PCR from FR4 total RNA using the primers shown in Fig. 7A, and was subsequently subcloned and sequenced. The deduced amino acid sequence is shown above the nucleotide sequence in one-letter code and is numbered on the right with position 1 set to the first codon of the signal peptide. The predicted site for signal peptidase cleavage was derived as previously stated above and is marked by an arrowhead. The polyadenylation signal AATAAA is underlined. The Calpha transmembrane domain is underlined. The MUM2 portion of the cDNA is shown on italics. H, HindIII; B, BamHI; X, XhoI; S α , IgA switch region; EC, extracellular

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region; TM, transmembrane; CYT, cytoplasmic domain.

Figures 8A-8C. Molecular cloning of the translocation
5 t(1;14)(q21;q32) in the FR4 multiple
myeloma cell line. Fig. 8A) Schematic
representation of the phage clones
representing der(14) and der(1) breakpoints
and the germline IGH and 1q21 loci.
10 Chromosome 14 sequences are indicated by a
solid black line with black boxes
representing Ca1 exons. Chromosome 1
sequences are shown as a grey line. The
probes used for chromosomal mapping are
15 indicated below the map. Restriction
enzyme codes are: B, BamHI; H, HindIII; X,
XhoI; S, SacI; E, EcoRI. For enzymes
marked by (*) only sites delineating the
probes are shown. Sa: IgA switch region;
20 LCR: 3'IgH locus control region. Fig. 8B)
Nucleotide sequence of the breakpoint
junctions and their alignment to the
corresponding germline regions of
chromosomes 14 and 1. Fig. 8C) Left,
25 fluorescence in situ hybridization (FISH)
analysis on human normal metaphase spreads
with the PAC clone 49A16 (Fig. 13) spanning
the germline1q21 region at the FR4
breakpoint. Right, DAPI stained image from
30 the same metaphase spread.

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Figures 9A-9B. Structure of *IRTA1* and *IRTA2* cDNAs. Figs. 9A,9B) Schematic representation of the full-length *IRTA1* (Fig. 9A) and *IRTA2* (Fig. 9B) cDNAs. Pattern-filled, wide boxes represent coding domains and narrow boxes represent untranslated regions (UTR). The predicted site for signal peptidase cleavage is marked by an arrowhead and was derived according to the SignalIP World Wide Web server at <http://www.cbs.dtu.dk/services/SignalIP>. The transmembrane domain prediction algorithm is described in Tusnady et al, 1998. SP, signal peptide; EC, extracellular domain; Ig, immuno-globulin-type; TM, transmembrane domain; CYT, cytoplasmic domain; A(n), polyA tail; GPI, glycoposphatidyl inositol. In (Fig. 9A), arrows in the 3' UTR indicate different polyadenylation addition sites utilized in the *IRTA1* cDNA. In (Fig. 9B), different 3'UTR regions in *IRTA2* isoforms are differentially shaded. Bars underneath the UTR regions in (Fig. 9A) and (Fig. 9B) identify probes used for Northern blot analysis in Figure 12.

Figures 10A-10B. Comparison of the amino acid sequences of *IRTA1* and *IRTA2* with members of the Fc Receptor family Fig. 10A) Multiple sequence alignment of the first two (top) and the third (bottom) extracellular Ig-domains of *IRTA1* and

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5 IRTA2 to Fc receptor family members. The sequences were compared using the ClustalW program (Thompson et al., 1994). Black-shaded boxes indicate conserved aminoacids among all sequences; dark-grey shaded boxes indicate conserved aminoacids among at least half of the sequences; light-shaded boxes indicate conservative substitutions. Fig. 10B) Alignment of the SH2-binding domains of IRTA1 and IRTA2 with the ITAM and ITIM consensus motifs. Conserved aminoacid positions are in bold. Symbol X represents any aminoacid.

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Figures 11A-11B-4. IRTA1 expression pattern. Fig. 11A) Left panel. Northern blot analysis of IRTA1 mRNA expression in tissues of the human immune system. Each lane contains 2mg mRNA. The position of RNA molecular weight markers is depicted on the right side of the blot. The positions of the IRTA1 and GAPDH mRNA transcripts are shown by arrows. (A GAPDH probe was included in the hybridization as an internal control-0.15 ng labelled + 50 ng unlabelled probe-). Right Panel.

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30 Northern blot analysis of IRTA1 expression in total RNA from the ER/EB

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cell line (10 mg per lane). For this experiment, cells were grown in the presence of estrogen (1mg/ml), followed by estrogen withdrawal for the indicated times. Arrows indicate the positions of the corresponding mRNAs. a, b and c correspond to the IRTA1 differentially polyadenylated species. The same blot was stripped and reprobed with a MYC cDNA probe (exon 2) to verify cellular G₀/G₁ arrest. Densitometric analysis of IRTA1 mRNA levels is plotted in the adjacent column graph. The cDNA probe used is shown as a solid bar underneath the IRTA1 mRNA scheme in Figure 9A. Fig. 11B-1-11B-4) *In situ* hybridization analysis of IRTA1 expression in serial sections of human tonsil. 1. Sense IRTA1 probe 2. Antisense IRTA1 probe 3. H&E staining 4. Antisense IRTA1 signal superimposed over an H&E stained section. GC, germinal center, MargZ, marginal zone

25

Figure 12A-12B-4. IRTA2 expression pattern. Fig. 12A) Northern blot analysis of IRTA2 mRNA expression in multiple human tissues (left panel) and in various lymphoid and non-lymphoid cell lines (right panel). Each lane contains 2mg mRNA.

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5 The positions of the *IRTA2* and *GAPDH* transcripts are shown by arrows. a, b, c and d correspond to the alternatively spliced *IRTA2* mRNA isoforms. RD, NC42 and CB33, Epstein-Barr virus transformed B lymphoblastoid cell lines; EREB, conditional EBV-transformed B lymphoblastoid cell line; FR4, plasma cell line; MOLT4 and HUT78, T cell lines; HL60 and U937, myelomonocytic cell lines; K562, erythroid cell line. The cDNA probe used is shown as a solid bar underneath the *IRTA2* mRNA scheme in Figure 9B. Figs. 12B-1-12B-4) *In situ* hybridization analysis of *IRTA2* mRNA expression in human tonsil. Fig. 12B-1. Sense *IRTA2* cDNA probe, Fig. 12B-2. Antisense *IRTA2* cDNA probe, Fig. 12B-3. H&E staining, Fig. 12B-4. Antisense *IRTA2* cDNA probe signal superimposed over H&E stained section. GC, germinal center, MargZ, marginal zone

25 **Figure 13.** Map of the germline 1q21 region spanning the FR4 breakpoint and genomic organization of *IRTA1* and *IRTA2*. Primers used to amplify *IRTA1* exons from spleen cDNA are marked by arrowheads on top panel. Black and light boxes indicate coding and non-coding exons respectively. Arrows indicate

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position of *BCL9*, *MUC1*, *IRTA* family and *FCGRIIB* loci. S, SacI; H, HindIII; S, SmaI; Pc, PacI; P, PmeI; Mb, Megabases

5 **Figures 14A-14D.** t(1;14)(q21;q32) in FR4 generates an
IRTA1/C α fusion transcript. Fig. 14A) Schematic representation of the
der(14) genomic clone 1FR4B-5 and of the germline IgC α locus. The FR4
breakpoint is marked by an arrow. Filled and open boxes represent the
10 IRTA1 and C α coding and non-coding exons respectively. Fig. 14B) Northern blot analysis with an IRTA1
exon 1 probe (shown by a bar in Fig. 14A) on FR4 and additional cell lines
15 detects an abnormal message in FR4. Arrowheads point to the location of normal IRTA1 message in ER/EB mRNA.
JUN3 and U266, myeloma cell lines. Two mg of polyA+ RNA loaded per lane. Fig. 14C) Schematic representation of
20 the IRTA1/C α fusion cDNA in FR4. The cDNA was amplified by RT-PCR from FR4 total RNA using the primers shown in
(Fig. 14A), and sequenced after subcloning. Fig. 14D) SDS/PAGE
25 analysis of immunoprecipitates obtained from vector control transfected and IRTA1/C α transient
expression construct transfected 293-T

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cells (lanes 1 & 2), or the following cell lines: mIgA positive lymphoblastoid cell line-Dakiki (lane 3), FR4 (lane 4), mIgM positive NHL cell line-Ramos (lane 5). H, HindIII; B, BamHI; X, XhoI; Sa, IgA switch region; EC, extracellular region; TM, transmembrane; CYT, cytoplasmic

10 **Figures 15A-15B.**

IRTA2 expression is deregulated in cell lines carrying 1q21 abnormalities. Figs. 15A, 15B) Northern blot analysis of IRTA2 mRNA expression in Burkitt lymphoma (Fig. 15A) and Multiple Myeloma (Fig. 15B) cell lines. The cDNA probe used is the same as in Fig. 12. Each lane contains 2mg mRNA. The positions of the IRTA2 and GAPDH mRNA transcripts are shown by dashes and arrows, respectively. The relative levels of IRTA2 mRNA expression in the left panel (Fig. 15A) were plotted on the right panel (Fig. 15A) after densitometric analysis and normalization versus the GAPDH levels. The right panel of (Fig. 15B) is a summary of the Northern blot analysis results.

30

Figures 16-1-16-4

IRTA1 expression in normal lymphoid tissue. Paraffin-embedded sections

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from normal human tonsil were stained with the following antibodies: Fig. 16-1) Negative control; Fig. 16-2) anti-CD3 mouse monoclonal to detect T cells; Fig. 16-3) anti-IRTA1 (mIRTA) mouse monoclonal; Fig. 16-4) anti-IRTA1 (J92884K) rabbit polyclonal. IRTA1 positive cells are located in the perifollicular and intraepithelial region of the tonsil, the equivalent of the marginal zone in the spleen.

Figure 17 IRTA1 expression in a stomach Mucosa-Associated-Lymphoid Tissue (MALT) B cell lymphoma. A paraffin-embedded section from a stomach MALT B cell lymphoma was stained with the anti-IRTA1 (mIRTA) mouse monoclonal antibody and counterstained with H&E. The majority of MALT lymphomas analyzed were IRTA1 positive. This antibody therefore can be an effective tool in the differential diagnosis of MALT lymphoma. The mIRTA1 antibody may also be proven useful in the therapy of this B cell tumor, similarly to the use of the anti-CD20 antibody (Rituximab) in the therapy of relapsed CD20-positive lymphomas (Foon K., Cancer J. 6: p273).

Figure 18A. IRTA1 cDNA and the amino acid sequence of the encoded IRTA1 protein.

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- Figures 18B-1-18B-3. IRTA2 cDNA and the amino acid sequence of the encoded IRTA2 protein.
- 5 Figures 18C-1-18C-2. IRTA3 cDNA and the amino acid sequence of the encoded IRTA3 protein.
- 10 Figures 18D-1-18D-2. IRTA4 cDNA and the amino acid sequence of the encoded IRTA4 protein.
- 15 Figures 18E-1-18E-2. IRTA5 cDNA and the amino acid sequence of the encoded IRTA5 protein.

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DETAILED DESCRIPTION OF THE INVENTION

The following standard abbreviations are used throughout the specification to indicate specific nucleotides: C=cytosine; A=adenosine; T=thymidine and G=guanosine.

5

This invention provides an isolated nucleic acid molecule which encodes immunoglobulin receptor, Immunoglobulin superfamily Receptor Translocation Associated, IRTA, protein.

10

As used herein "Immunoglobulin Receptor Translocation Associated" genes, "IRTA" are nucleic acid molecules which encode novel immunoglobulin superfamily cell surface receptors in B cells which are important in B cell development, and whose abnormal expression, e.g. deregulated expression, perturbs cell surface B cell immunological responses and thus is involved in B cell malignancy, including lymphomagenesis.

20 Nucleic acid molecules encoding proteins designate "MUM-2" and "MUM-3" proteins in the First Series of Experiments are now called "IRTA-1" and "IRTA-2" genes, i.e. nucleic acid molecules which encode IRTA-1 and IRTA-2 proteins respectively. IRTA-3, -4 and -5 proteins are members of
25 the same the immunoglobulin gene superfamily as are the IRTA-1 and IRTA-2 proteins.

In an embodiment of the above-described isolated nucleic acid molecule which encodes immunoglobulin receptor,
30 Immunoglobulin superfamily Receptor Translocation Associated, IRTA, protein, the encoded IRTA protein is

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IRTA1 protein comprising the amino acid sequence set forth in Figure 18A (SEQ ID NO:1).

In another embodiment of the above-described isolated
5 nucleic acid molecule, the encoded IRTA protein is IRTA2 protein comprising the amino acid sequence set forth in Figures 18B-1-18B-3 (SEQ ID NO:3).

In a further embodiment of the above-described isolated
10 nucleic acid molecule, the encoded IRTA protein is IRTA3 protein comprising the amino acid sequence set forth in Figures 18C-1-18C-2 (SEQ ID NO:5).

In yet another embodiment of the above-described isolated
15 nucleic acid molecule, the encoded IRTA protein is IRTA4 protein comprising the amino acid sequence set forth in Figures 18D-1-18D-2 (SEQ ID NO: 7).

In a still further embodiment of the above-described
20 isolated nucleic acid molecule, the encoded IRTA protein is IRTA5 protein comprising the amino acid sequence set forth in Figures 18E-1-18E-2 (SEQ ID NO: 9).

In another embodiment of any of the above-described
25 isolated nucleic acid molecules, the nucleic acid molecule is DNA. In further embodiments, the DNA is cDNA. In additional embodiments, the DNA is genomic DNA. In another embodiment, the nucleic acid molecule is an RNA molecule. In yet another embodiment, the DNA molecule is
30 cDNA having the nucleotide sequence set forth in Figure 18A (SEQ ID NO:2). In another embodiment, the DNA molecule is cDNA having the nucleotide sequence set forth in Figure

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18A (SEQ ID NO:4). In a further embodiment, the DNA molecule is cDNA having the nucleotide sequence set forth in Figure 18A (SEQ ID NO:6). In another embodiment, the DNA molecule is cDNA having the nucleotide sequence set forth in Figure 18A (SEQ ID NO:8). In an embodiment, the DNA molecule is cDNA having the nucleotide sequence set forth in Figure 18A (SEQ ID NO:10). In preferred embodiments of the isolated nucleic acid molecule, wherein the nucleic acid molecules encode human IRTA1, IRTA2, IRTA3, IRTA4 or IRTA5 protein. In additional embodiments, the nucleic acid molecules encode mammalian IRTA1 protein. The mammalian IRTA1 protein may be murine IRTA1 protein. In another preferred embodiment, the isolated nucleic acid molecules are operatively linked to a promoter of DNA transcription. In yet another preferred embodiment of the isolated nucleic acid molecule, the promoter comprises a bacterial, yeast, insect, plant or mammalian promoter.

This invention provides a vector comprising any of the above-described isolated nucleic acid molecule encoding IRTA proteins, including but not limited to mammalian IRTA proteins, of which human and murine are preferred.

In an embodiment, the vector is a plasmid.

This invention provides a host cell comprising the above-described vector comprising any of the above-described isolated nucleic acid molecule encoding IRTA proteins. Preferably, the isolated nucleic acid molecules in such vectors are operatively linked to a promoter of DNA transcription. In another embodiment of the host cell, the cell is selected from a group consisting of a

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bacterial cell, a plant cell, and insect cell and a mammalian cell.

This invention provides a method of producing an IRTA polypeptide (protein) which comprises: (a) introducing a vector comprising an isolated nucleic acid which encodes an immunoglobulin receptor, Immunoglobulin superfamily Receptor Translocation Associated, IRTA, protein into a suitable host cell; and (b) culturing the resulting cell so as to produce the polypeptide. In further embodiments, the IRTA protein produced by the above-described method may be recovered and in a still further embodiment, may be purified either wholly or partially. In an embodiment the IRTA protein may be any of IRTA1, IRTA2, IRTA3, IRTA4, or IRTA5 protein. In further embodiments, any of the IRTA proteins may be mammalian proteins. In still further embodiments, the mammalian proteins may be human or mouse IRTA proteins.

IRTA genes (nucleic acid molecules encoding IRTA proteins IRTA1, IRTA2, IRTA3, IRTA4 and IRTA5) are useful for the production of the IRTA proteins encoded thereby. IRTA proteins are useful for production of antibodies; such antibodies are used as reagents for differential diagnosis of lymphoma subtypes in hematopathology. Antibodies directed against IRTA proteins and which bind specifically to IRTA proteins also have therapeutic uses, i.e. to specifically target tumor cells, which may be used and administered similarly to "Rituximab" (an anti-CD20 antibody), which is an antibody approved by the FDA for therapy of relapsed CD20-positive lymphomas (Foon K., Cancer J. 6(5):273). Anti-IRTA1, anti-IRTA2, anti-IRTA3,

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anti-IRTA4 and anti-IRTA5 antibodies are also useful markers for isolation of specific subsets of B cells in research studies of normal and tumor B cell biology. Moreover, Anti-IRTA1, anti-IRTA2, anti-IRTA3, anti-IRTA4
5 and anti-IRTA5 antibodies are useful research reagents to experimentally study the biology of signaling in normal and tumor B cells.

Methods of introducing nucleic acid molecules into cells
10 are well known to those of skill in the art. Such methods include, for example, the use of viral vectors and calcium phosphate co-precipitation. Accordingly, nucleic acid molecules encoding IRTA proteins IRTA1, IRTA2, IRTA3, IRTA4 and IRTA5 may be introduced into cells for the
15 production of these IRTA proteins.

Numerous vectors for expressing the inventive proteins IRTA1, IRTA2, IRTA3, IRTA4, and IRTA5, may be employed. Such vectors, including plasmid vectors, cosmid vectors,
20 bacteriophage vectors and other viruses, are well known in the art. For example, one class of vectors utilizes DNA elements which are derived from animal viruses such as bovine papilloma virus, polyoma virus, adenovirus, vaccinia virus, baculovirus, retroviruses (RSV, MMTV or
25 MoMLV), Semliki Forest virus or SV40 virus. Additionally, cells which have stably integrated the DNA into their chromosomes may be selected by introducing one or more markers which allow for the selection of transfected host cells. The markers may provide, for example, prototrophy
30 to an auxotrophic host, biocide resistance or resistance to heavy metals such as copper. The selectable marker gene can be either directly linked to the DNA sequences to

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be expressed, or introduced into the same cell by cotransformation.

Regulatory elements required for expression include
5 promoter sequences to bind RNA polymerase and
transcription initiation sequences for ribosome binding.
Additional elements may also be needed for optimal
synthesis of mRNA. These additional elements may include
splice signals, as well as enhancers and termination
10 signals. For example, a bacterial expression vector
includes a promoter such as the lac promoter and for
transcription initiation the Shine-Dalgarno sequence and
the start codon AUG. Similarly, a eukaryotic expression
vector includes a heterologous or homologous promoter for
15 RNA polymerase II, a downstream polyadenylation signal,
the start codon AUG, and a termination codon for
detachment of the ribosome. Such vectors may be obtained
commercially or assembled from the sequences described by
methods well known in the art, for example the methods
20 described above for constructing vectors in general.

These vectors may be introduced into a suitable host cell
to form a host vector system for producing the inventive
proteins. Methods of making host vector systems are well
25 known to those skilled in the art.

Suitable host cells include, but are not limited to,
bacterial cells (including gram positive cells), yeast
cells, fungal cells, insect cells and animal cells.
30 Suitable animal cells include, but are not limited to HeLa
cells, Cos cells, CV1 cells and various primary mammalian
cells. Numerous mammalian cells may be used as hosts,

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including, but not limited to, the mouse fibroblast cell NIH-3T3 cells, CHO cells, HeLa cells, Ltk⁻ cells and COS cells. Mammalian cells may be transfected by methods well known in the art such as calcium phosphate precipitation, electroporation and microinjection.

This invention provides an isolated nucleic acid molecule comprising at least 15 contiguous nucleotides capable of specifically hybridizing with a unique sequence included within the sequence of the isolated nucleic acid molecule encoding IRTA protein. In an embodiment, the IRTA protein may be IRTA1, IRTA2, IRTA3, IRTA4 or IRTA5 protein, or fragment(s) thereof, having the amino acid sequence set forth in any of Figures 18A, 18B-1-18B-3, 18C-1-18C-2, 18D-1-18D-2 or 18E-1-18E-2, respectively. In other embodiments, the isolated nucleic acid molecules are labeled with a detectable marker. In still other embodiments of the isolated nucleic acid molecules, the detectable marker is selected from the group consisting of a radioactive isotope, enzyme, dye, biotin, a fluorescent label or a chemiluminescent label.

This invention provides a method for detecting a B cell malignancy or a type of B cell malignancy in a sample from a subject wherein the B cell malignancy comprises a 1q21 chromosomal rearrangement which comprises: a) obtaining RNA from the sample from the subject; b) contacting the RNA of step (a) with a nucleic acid molecule of at least 15 contiguous nucleotides capable of specifically hybridizing with a unique sequence included within the sequence of an isolated RNA encoding human IRTA protein selected from the group consisting of human IRTA1, IRTA2,

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IRTA3, IRTA4 and IRTA5, under conditions permitting hybridization of the RNA of step (a) with the nucleic acid molecule capable of specifically hybridizing with a unique sequence included within the sequence of an isolated RNA
5 encoding human IRTA protein, wherein the nucleic acid molecule is labeled with a detectable marker; and c) detecting any hybridization in step (b), wherein detection of hybridization indicates presence of B cell malignancy or a type of B cell malignancy in the sample.

10

Detection of hybridization of RNA encoding IRTA proteins will indicate that a malignancy is a B cell malignancy. More specifically, detection of hybridization of RNA encoding ITRA1 protein indicates that the B cell
15 malignancy is a Mucosa-Associated-Lymphoid Tissue (MALT) B cell lymphoma. Detection of hybridization of RNA encoding ITRA4 and IRTA5 proteins indicate that the B cell malignancy is a mantle cell lymphoma. In an embodiment of the above-described method, the B cell malignancy
20 comprises a 1q21 chromosomal rearrangement. One of skill will use the above-described method as a diagnostic aid in conjunction with other standard methods of detecting/diagnosing malignancies, e.g. pathology of a tumor sample, which may indicate lymphoma and the above-
25 described method will then narrow the malignancy to a B cell lymphoma or more specifically to MALT) B cell lymphoma or a mantle cell lymphoma as discussed supra.

One of skill is familiar with known methods of detecting
30 of hybridization nucleic acid molecules to nucleic acid oligonucleotides, i.e. nucleic acid probes encoding a protein of interest for diagnostic methods. The nucleic

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acid molecules encoding the IRTA proteins of the subject invention are useful for detecting B cell malignancy. One of skill will recognize that variations of the above-described method for detecting a B cell malignancy in a sample include, but are not limited to, digesting nucleic acid from the sample with restriction enzymes and separating the nucleic acid molecule fragments so obtained by size fractionation before hybridization.

10 In an embodiment of the above-described method for detecting a B cell malignancy in a sample from a subject, wherein the detectable marker is radioactive isotope, enzyme, dye, biotin, a fluorescent label or a chemiluminescent label. In a preferred embodiment, the B cell malignancy is selected from the group consisting of B cell lymphoma, multiple myeloma, Burkitt's lymphoma, marginal zone lymphoma, diffuse large cell lymphoma and follicular lymphoma cells. In a further embodiment, the B cell lymphoma is Mucosa-Associated-Lymphoid Tissue B cell lymphoma (MALT). In another preferred embodiment, the B cell lymphoma is non-Hodgkin's lymphoma.

This invention provides an antisense oligonucleotide having a sequence capable of specifically hybridizing to an mRNA molecule encoding a human ITRA protein so as to prevent overexpression of the mRNA molecule.

In preferred embodiments of the antisense oligonucleotide, the ITRA protein selected from the group consisting of human IRTA1, IRTA2, IRTA3, IRTA4 and IRTA5 protein. In further embodiments of any of the above-described oligonucleotides of nucleic acid molecules encoding the

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IRTA1, IRTA2, IRTA3, IRTA4 and/or IRTA5 proteins, the nucleic acid may be genomic DNA or cDNA.

One of skill is familiar with conventional techniques for
5 nucleic acid hybridization of oligonucleotides, e.g. Ausubel, F.M. et al. *Current Protocols in Molecular Biology*, (John Wiley & Sons, New York, 1998), for example stringent conditions of 65°C in the presence of an elevated salt concentration. Such conditions are used for
10 completely complementary nucleic acid hybridization, whereas conditions that are not stringent are used for hybridization of nucleic acids which are not totally complementary.

15 As used herein, the phrase "specifically hybridizing" means the ability of a nucleic acid molecule to recognize a nucleic acid sequence complementary to its own and to form double-helical segments through hydrogen bonding between complementary base pairs. As used herein, a
20 "unique sequence" is a sequence specific to only the nucleic acid molecules encoding the IRTA1, IRTA2, IRTA3, IRTA4 and IRTA5 proteins. Nucleic acid probe technology is well known to those skilled in the art who will readily appreciate that such probes may vary greatly in length and
25 may be labeled with a detectable label, such as a radioisotope or fluorescent dye, to facilitate detection of the probe. Detection of nucleic acid molecules encoding the IRTA1, IRTA2, IRTA3, IRTA4 and/or IRTA5 proteins is useful as a diagnostic test for any disease
30 process in which levels of expression of the corresponding IRTA1, IRTA2, IRTA3, IRTA4 and/or IRTA5 proteins is altered. DNA probe molecules are produced by insertion of

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a DNA molecule which encodes mammalian IRTA1, IRTA2, IRTA3, IRTA4 and/or IRTA5 proteins or fragments thereof into suitable vectors, such as plasmids or bacteriophages, followed by insertion into suitable bacterial host cells and replication and harvesting of the DNA probes, all using methods well known in the art. For example, the DNA may be extracted from a cell lysate using phenol and ethanol, digested with restriction enzymes corresponding to the insertion sites of the DNA into the vector (discussed herein), electrophoresed, and cut out of the resulting gel. The oligonucleotide probes are useful for 'in situ' hybridization or in order to locate tissues which express this IRTA gene family, and for other hybridization assays for the presence of these genes (nucleic acid molecules encoding any of the IRTA1-IRTA5 proteins) or their mRNA in various biological tissues. In addition, synthesized oligonucleotides (produced by a DNA synthesizer) complementary to the sequence of a DNA molecule which encodes an IRTA1, IRTA2, IRTA3, IRTA4 or IRTA5 protein are useful as probes for these genes, for their associated mRNA, or for the isolation of related genes by homology screening of genomic or cDNA libraries, or by the use of amplification techniques such as the Polymerase Chain Reaction.

25

This invention provides a purified IRTA1 protein comprising the amino acid sequence set forth in Figure 18A (SEQ ID NO:1). In an embodiment of the purified IRTA1 protein, wherein the IRTA1 protein is human IRTA1.

30

This invention provides a purified IRTA2 protein comprising the amino acid sequence set forth in Figures

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18B-1-18B-3 (SEQ ID NO:3). In an embodiment of the purified IRTA2 protein, the IRTA2 protein is human IRTA2.

5 This invention provides a purified IRTA3 protein comprising the amino acid sequence set forth in Figures 18C-1-18C-2 (SEQ ID NO:5). In an embodiment of the purified IRTA3 protein, the IRTA3 protein is human IRTA3.

10 This invention provides a purified IRTA4 protein comprising the amino acid sequence set forth in Figures 18D-1-18D-2 (SEQ ID NO: 7). In an embodiment of the purified IRTA3 protein, wherein the IRTA4 protein is human IRTA4.

15 This invention provides a purified IRTA5 protein comprising the amino acid sequence set forth in Figures 18E-1-18E-2 (SEQ ID NO: 9). In an embodiment of the purified IRTA5 protein, the IRTA5 protein is human IRTA5.

20 In order to facilitate an understanding of the Experimental Details section which follows, certain frequently occurring methods and/or terms are best described in Sambrook, et al.(1989) and Harlow & Lane, Antibodies: A Laboratory Manual, Cold Spring Harbor
25 Laboratories, Cold Spring Harbor, NY: 1988.

This invention provides an antibody/antibodies directed to an epitope of a purified IRTA1, IRTA2, IRTA3, IRTA4 or IRTA5 protein, or fragment(s) thereof, having the amino
30 acid sequence set forth in any of Figures 18A, 18B-1-18B-3, 18C-1-18C-2, 18D-1-18D-2 or 18E-1-18E-2.

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As used herein, the term "antibody" includes, but is not limited to, both naturally occurring and non-naturally occurring antibodies. Specifically, the term "antibody" includes polyclonal and monoclonal antibodies, and binding fragments thereof. Furthermore, the term "antibody" includes chimeric antibodies and wholly synthetic antibodies, and fragments thereof. The polyclonal and monoclonal antibodies may be "purified" which means the polyclonal and monoclonal antibodies are free of any other antibodies. As used herein, partially purified antibody means an antibody composition which comprises antibodies which specifically bind to any of the IRTA protein(s) of the subject invention, and consists of fewer protein impurities than does the serum from which the antibodies are derived. A protein impurity is a protein other than the antibodies specific for the IRTA protein(s) of the subject invention. For example, the partially purified antibodies may be an IgG preparation.

20 Polyclonal antibodies (anti-IRTA antibodies) may be produced by injecting a host animal such as rabbit, rat, goat, mouse or other animal with the immunogen(s) of this invention, e.g. a purified human IRTA1, IRTA2, IRTA3, IRTA4 or IRTA5, described infra. The sera are extracted from the host animal and are screened to obtain polyclonal antibodies which are specific to the immunogen. Methods of screening for polyclonal antibodies are well known to those of ordinary skill in the art such as those disclosed in Harlow & Lane, Antibodies: A Laboratory Manual, (Cold Spring Harbor Laboratories, Cold Spring Harbor, NY: 1988)

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the contents of which are hereby incorporated by reference.

The anti-IRTA monoclonal antibodies of the subject invention may be produced by immunizing for example, mice
5 with an immunogen (the IRTA polypeptides or fragments thereof as described herein). The mice are inoculated intraperitoneally with an immunogenic amount of the above-described immunogen and then boosted with similar amounts of the immunogen. Spleens are collected from the
10 immunized mice a few days after the final boost and a cell suspension is prepared from the spleens for use in the fusion.

Hybridomas may be prepared from the splenocytes and a
15 murine tumor partner using the general somatic cell hybridization technique of Kohler, B. and Milstein, C., Nature (1975) 256: 495-497. Available murine myeloma lines, such as those from the American Type Culture Collection (ATCC), 10801 University Boulevard, Manassas,
20 VA 20110-2209, USA, may be used in the hybridization. Basically, the technique involves fusing the tumor cells and splenocytes using a fusogen such as polyethylene glycol. After the fusion the cells are separated from the fusion medium and grown in a selective growth medium, such
25 as HAT medium, to eliminate unhybridized parent cells. The hybridomas may be expanded, if desired, and supernatants may be assayed by conventional immunoassay procedures, for example radioimmunoassay, using the immunizing agent as antigen. Positive clones may be
30 characterized further to determine whether they meet the criteria of the invention antibodies.

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Hybridomas that produce such antibodies may be grown in vitro or in vivo using known procedures. The monoclonal antibodies may be isolated from the culture media or body fluids, as the case may be, by conventional immunoglobulin
5 purification procedures such as ammonium sulfate precipitation, gel electrophoresis, dialysis, chromatography, and ultrafiltration, if desired.

In the practice of the subject invention any of the above-
10 described antibodies may be labeled with a detectable marker. In one embodiment, the labeled antibody is a purified labeled antibody. The term "antibody" includes, by way of example, both naturally occurring and non-naturally occurring antibodies. Specifically, the term
15 "antibody" includes polyclonal and monoclonal antibodies, and fragments thereof. Furthermore, the term "antibody" includes chimeric antibodies and wholly synthetic antibodies, and fragments thereof. A "detectable moiety" which functions as detectable labels are well known to
20 those of ordinary skill in the art and include, but are not limited to, a fluorescent label, a radioactive atom, a paramagnetic ion, biotin, a chemiluminescent label or a label which may be detected through a secondary enzymatic or binding step. The secondary enzymatic or binding step
25 may comprise the use of digoxigenin, alkaline phosphatase, horseradish peroxidase, β -galactosidase, fluorescein or streptavidin/biotin. Methods of labeling antibodies are well known in the art.

30 Methods of recovering serum from a subject are well known to those skilled in the art. Methods of partially purifying antibodies are also well known to those skilled

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in the art, and include, by way of example, filtration, ion exchange chromatography, and precipitation.

5 The polyclonal and monoclonal antibodies of the invention may be labeled with a detectable marker. In one embodiment, the labeled antibody is a purified labeled antibody. The detectable marker may be, for example, a radioactive or fluorescent marker. Methods of labeling antibodies are well known in the art.

10

Determining whether the polyclonal and monoclonal antibodies of the subject invention bind to cells, e.g. cancer cells, expressing an IRTA protein and form a complex with one or more of the IRTA protein(s) described herein, or fragments thereof, on the surface of said cells, may be accomplished according to methods well known to those skilled in the art. In the preferred embodiment, the determining is accomplished according to flow cytometry methods.

20

The antibodies of the subject invention may be bound to an insoluble matrix such as that used in affinity chromatography. Cells which form a complex, i.e. bind, with the immobilized polyclonal or monoclonal antibody may be isolated by standard methods well known to those skilled in the art. For example, isolation may comprise affinity chromatography using immobilized antibody.

30 Alternatively, the antibody may be a free antibody. In this case, isolation may comprise cell sorting using free, labeled primary or secondary antibodies. Such cell sorting

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methods are standard and are well known to those skilled in the art.

This invention provides an antibody directed to a purified
5 IRTA protein selected from the group consisting of IRTA1,
IRTA2, IRTA3, IRTA4 and IRTA5. In a preferred embodiment
of the anti-IRTA antibody the IRTA protein is human IRTA
protein. The IRTA protein may be any mammalian IRTA
protein, including a murine IRTA protein. In a further
10 embodiment of any the above-described antibodies, the
antibody is a monoclonal antibody. In another embodiment,
the monoclonal antibody is a murine monoclonal antibody or
a humanized monoclonal antibody. As used herein,
"humanized" means an antibody having characteristics of a
15 human antibody, such antibody being non-naturally
occurring, but created using hybridoma techniques wherein
the antibody is of human origin except for the antigen
determinant portion, which is murine. In yet another
embodiment, the antibody is a polyclonal antibody.

20

In preferred embodiments, any of the antibodies of the
subject invention may be conjugated to a therapeutic
agent. In further preferred embodiments, the therapeutic
agent is a radioisotope, toxin, toxoid, or
25 chemotherapeutic agent. The conjugated antibodies of the
subject invention may be administered to a subject having
a B cell cancer in any of the methods provided below.

This invention provides a pharmaceutical composition
30 comprising an amount of the antibody directed to an IRTA
protein effective to bind to cancer cells expressing an
IRTA protein selected from the group consisting of human

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IRTA1, IRTA2, IRTA3, IRTA4 and IRTA5 so as to prevent growth of the cancer cells and a pharmaceutically acceptable carrier. The anti-IRTA antibody may be directed to an epitope of an IRTA protein selected from the group consisting of IRTA1, IRTA2, IRTA3, IRTA4 and IRTA5. The IRTA proteins may be human or mouse IRTA proteins.

In preferred embodiments of the above-described pharmaceutical composition, the cancer cells are selected from the group consisting of B cell lymphoma, multiple myeloma, a mantle cell lymphoma, Burkitt's lymphoma, marginal zone lymphoma, diffuse large cell lymphoma and follicular lymphoma cells. In another preferred embodiment of the pharmaceutical composition, the B cell lymphoma cells are Mucosa-Associated-Lymphoid Tissue B cell lymphoma (MALT) cells. In another preferred embodiment of the pharmaceutical composition, the B cell lymphoma cells are non-Hodgkin's lymphoma cells.

This invention provides a pharmaceutical composition comprising an amount of any of the above-described oligonucleotides effective to prevent overexpression of a human IRTA protein and a pharmaceutically acceptable carrier capable. In preferred embodiments of the pharmaceutical composition the oligonucleotide is a nucleic acid molecule which encodes an IRTA protein selected from the group consisting of IRTA1, IRTA2, IRTA3, IRTA4 and IRTA5. The IRTA proteins may be human or mouse IRTA proteins.

30

As used herein, "malignant" means capable of metastasizing. As used herein, "tumor cells" are cells

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which originate from a tumor, i.e., from a new growth of different or abnormal tissue. The tumor cells and cancer cells may exist as part of the tumor mass, or may exist as free-floating cells detached from the tumor mass from which they originate.

As used herein, malignant cells include, but are in no way limited to, B cell lymphoma, multiple myeloma, Burkitt's lymphoma, mantle cell lymphoma, marginal zone lymphoma, diffuse large cell lymphoma and follicular lymphoma. The B cell lymphoma is Mucosa-Associated-Lymphoid Tissue B cell lymphoma (MALT) or is non-Hodgkin's lymphoma.

As used herein, "subject" is any animal or artificially modified animal. Artificially modified animals include, but are not limited to, SCID mice with human immune systems. In a preferred embodiment, the subject is a human.

This invention provides a method of diagnosing B cell malignancy which comprises a 1q21 chromosomal rearrangement in a sample from a subject which comprises:

- a) obtaining the sample from the subject; b) contacting the sample of step (a) with an antibody directed to a purified IRTA protein capable of specifically binding with a human IRTA protein selected from the group consisting of human IRTA1, IRTA2, IRTA3, IRTA4 and IRTA5 IRTA protein on a cell surface of a cancer cell under conditions permitting binding of the antibody with human IRTA protein on the cell surface of the cancer cell, wherein the antibody is labeled with a detectable marker; and c) detecting any binding in step (b), wherein detection of

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binding indicates a diagnosis of B cell malignancy in the sample.

In an embodiment of the above-described method of
5 diagnosing B cell malignancy, the IRTA protein is selected
from the group consisting of IRTA1, IRTA2, IRTA3, IRTA4
and IRTA5. In another embodiment of the method the IRTA
protein is human or mouse IRTA protein. In a further
embodiment IRTA protein is purified. In a preferred
10 embodiment of this method, the B cell malignancy is
selected from the group consisting of B cell lymphoma,
multiple myeloma, Burkitt's lymphoma, marginal zone
lymphoma, diffuse large cell lymphoma and follicular
lymphoma. In yet another embodiment of this method, the B
15 cell lymphoma is Mucosa-Associated-Lymphoid Tissue B cell
lymphoma (MALT). In another preferred embodiment of this
method, the B cell lymphoma is non-Hodgkin's lymphoma.

This invention provides a method of detecting human IRTA
20 protein in a sample which comprises: a) contacting the
sample with any of any of the above-described anti-IRTA
antibodies under conditions permitting the formation of a
complex between the antibody and the IRTA in the sample;
and b) detecting the complex formed in step (a), thereby
25 detecting the presence of human IRTA in the sample. In an
embodiment the IRTA protein detected may be an IRTA1,
IRTA2, IRTA3, IRTA4 or IRTA5 protein, having an amino acid
sequence set forth in any of Figures 18A, 18B-1-18B-3,
18C-1-18C-2, 18D-1-18D-2 or 18E-e-18E-2. As described
30 hereinabove detection of the complex formed may be
achieved by using antibody labeled with a detectable
marker and determining presence of labeled complex.

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Detecting human IRTA protein in a sample from a subject is another method of diagnosing B cell malignancy in a subject. In an embodiment of this method of diagnosis, the B cell malignancy is selected from the group consisting of B cell lymphoma, multiple myeloma, Burkitt's lymphoma, marginal zone lymphoma, diffuse large cell lymphoma and follicular lymphoma. In yet another embodiment of this method, the B cell lymphoma is Mucosa-Associated-Lymphoid Tissue B cell lymphoma (MALT). In another preferred embodiment of this method, the B cell lymphoma is non-Hodgkin's lymphoma.

This invention provides a method of treating a subject having a B cell cancer which comprises administering to the subject an amount of anti-IRTA antibody effective to bind to cancer cells expressing an IRTA protein so as to prevent growth of the cancer cells and a pharmaceutically acceptable carrier, thereby treating the subject. Growth and proliferation of the cancer cells is thereby inhibited and the cancer cells die. In an embodiment of the above-described method, the IRTA protein is selected from the group consisting of human IRTA1, IRTA2, IRTA3, IRTA4 and IRTA5. In a preferred embodiment of the above-described method of treating a subject having a B cell cancer, the anti-IRTA antibody is a monoclonal antibody. In another embodiment of the method, the monoclonal antibody is a murine monoclonal antibody or a humanized monoclonal antibody. The antibody may be a chimeric antibody. In a further embodiment, the anti-IRTA antibody is a polyclonal antibody. In an embodiment, the polyclonal antibody may be a murine or human polyclonal antibody. In a preferred embodiment, the B cell cancer is selected from

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the group consisting of B cell lymphoma, multiple myeloma, Burkitt's lymphoma, mantle cell lymphoma marginal zone lymphoma, diffuse large cell lymphoma and follicular lymphoma. In another preferred embodiment, the B cell lymphoma is Mucosa-Associated-Lymphoid Tissue B cell lymphoma (MALT). In a further preferred embodiment, the B cell lymphoma is non-Hodgkin's lymphoma. In a preferred embodiment of the above-described method of treating a subject having a B cell cancer, administration of the amount of anti-IRTA antibody effective to bind to cancer cells expressing an IRTA protein is intravenous, intraperitoneal, intrathecal, intralymphatic, intramuscular, intralesional, parenteral, epidural, subcutaneous; by infusion, liposome-mediated delivery, aerosol delivery; topical, oral, nasal, anal, ocular or otic delivery. In another preferred embodiment of the above-described methods, the anti-IRTA antibody may be conjugated to a therapeutic agent. In further preferred embodiments, the therapeutic agent is a radioisotope, toxin, toxoid, or chemotherapeutic agent.

This invention provides a method of treating a subject having a B cell cancer which comprises administering to the subject an amount of an antisense oligonucleotide having a sequence capable of specifically hybridizing to an mRNA molecule encoding a human IRTA protein so as to prevent overexpression of the human IRTA protein, so as to arrest cell growth or induce cell death of cancer cells expressing IRTA protein(s) and a pharmaceutically acceptable carrier, thereby treating the subject.

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In an embodiment of the above-described method of treating a subject having a B cell cancer, the IRTA protein is selected from the group consisting of human IRTA1, IRTA2, IRTA3, IRTA4 and IRTA5 protein. In a preferred embodiment, B cell cancer is selected from the group consisting of B cell lymphoma, multiple myeloma, Burkitt's lymphoma, marginal zone lymphoma, diffuse large cell lymphoma and follicular lymphoma. In another preferred embodiment, the B cell lymphoma is Mucosa-Associated-Lymphoid Tissue-B cell lymphoma (MALT). In a yet another preferred embodiment, the B cell lymphoma is non-Hodgkin's lymphoma. In embodiments of any of the above-described oligonucleotides of nucleic acid molecules encoding the IRTA1, IRTA2, IRTA3, IRTA4 and/or IRTA5 proteins, the nucleic acid may be genomic DNA or cDNA. In a further preferred embodiment of the above-described method of treating a subject having a B cell cancer, administration of the amount of oligonucleotide of effective to prevent overexpression of a human IRTA protein is intravenous, intraperitoneal, intrathecal, intralymphatic, intramuscular, intralesional, parenteral, epidural, subcutaneous; by infusion, liposome-mediated delivery, aerosol delivery; topical, oral, nasal, anal, ocular or otic delivery. In an embodiment of the above-described methods, the oligonucleotide may be conjugated to a therapeutic agent. In further preferred embodiments, the therapeutic agent is a radioisotope, toxin, toxoid, or chemotherapeutic agent.

The invention also provides a pharmaceutical composition comprising either an effective amount of the

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oligonucleotides or of the antibodies described above and a pharmaceutically acceptable carrier. In the subject invention an "effective amount" is any amount of an oligonucleotide or an antibody which, when administered to
5 a subject suffering from a disease or abnormality against which the oligonucleotide or antibody are effective, causes reduction, remission, or regression of the disease or abnormality. In the practice of this invention the "pharmaceutically acceptable carrier" is any physiological
10 carrier known to those of ordinary skill in the art useful in formulating pharmaceutical compositions. . . .

Pharmaceutically acceptable carriers are well known to those skilled in the art and include, but are not limited
15 to, 0.01-0.1M and preferably 0.05M phosphate buffer or 0.8% saline. Additionally, such pharmaceutically acceptable carriers may be aqueous or non-aqueous solutions, suspensions, and emulsions. Examples of non-aqueous solvents are propylene glycol, polyethylene
20 glycol, vegetable oils such as olive oil, and injectable organic esters such as ethyl oleate. Aqueous carriers include water, alcoholic/aqueous solutions, emulsions or suspensions, including saline and buffered media. Parenteral vehicles include sodium chloride solution,
25 Ringer's dextrose, dextrose and sodium chloride, lactated Ringer's or fixed oils. Intravenous vehicles include fluid and nutrient replenishers, electrolyte replenishers such as those based on Ringer's dextrose, and the like. Preservatives and other additives may also be present,
30 such as, for example, antimicrobials, antioxidants, chelating agents, inert gases and the like.

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In one preferred embodiment the pharmaceutical carrier may be a liquid and the pharmaceutical composition would be in the form of a solution. In another equally preferred embodiment, the pharmaceutically acceptable carrier is a solid and the composition is in the form of a powder or tablet. In a further embodiment, the pharmaceutical carrier is a gel and the composition is in the form of a suppository or cream. In a further embodiment the compound may be formulated as a part of a pharmaceutically acceptable transdermal patch.

A solid carrier can include one or more substances which may also act as flavoring agents, lubricants, solubilizers, suspending agents, fillers, glidants, compression aids, binders or tablet-disintegrating agents; it can also be an encapsulating material. In powders, the carrier is a finely divided solid which is in admixture with the finely divided active ingredient. In tablets, the active ingredient is mixed with a carrier having the necessary compression properties in suitable proportions and compacted in the shape and size desired. The powders and tablets preferably contain up to 99% of the active ingredient. Suitable solid carriers include, for example, calcium phosphate, magnesium stearate, talc, sugars, lactose, dextrin, starch, gelatin, cellulose, polyvinylpyrrolidone, low melting waxes and ion exchange resins.

Liquid carriers are used in preparing solutions, suspensions, emulsions, syrups, elixirs and pressurized compositions. The active ingredient can be dissolved or suspended in a pharmaceutically acceptable liquid carrier

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such as water, an organic solvent, a mixture of both or pharmaceutically acceptable oils or fats. The liquid carrier can contain other suitable pharmaceutical additives such as solubilizers, emulsifiers, buffers, 5 preservatives, sweeteners, flavoring agents, suspending agents, thickening agents, colors, viscosity regulators, stabilizers or osmo-regulators. Suitable examples of liquid carriers for oral and parenteral administration include water (partially containing additives as above, 10 e.g. cellulose derivatives, preferably sodium carboxymethyl cellulose solution), alcohols (including monohydric alcohols and polyhydric alcohols, e.g. glycols) and their derivatives, and oils (e.g. fractionated coconut oil and arachis oil). For parenteral administration, the 15 carrier can also be an oily ester such as ethyl oleate and isopropyl myristate. Sterile liquid carriers are useful in sterile liquid form compositions for parenteral administration. The liquid carrier for pressurized compositions can be halogenated hydrocarbon or other 20 pharmaceutically acceptable propellant.

Liquid pharmaceutical compositions which are sterile solutions or suspensions can be utilized by for example, intramuscular, intrathecal, epidural, intraperitoneal or 25 subcutaneous injection. Sterile solutions can also be administered intravenously. The compounds may be prepared as a sterile solid composition which may be dissolved or suspended at the time of administration using sterile water, saline, or other appropriate sterile injectable 30 medium. Carriers are intended to include necessary and inert binders, suspending agents, lubricants, flavorants, sweeteners, preservatives, dyes, and coatings.

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The pharmaceutical composition comprising the oligonucleotide or the antibody can be administered orally in the form of a sterile solution or suspension containing other solutes or suspending agents, for example, enough
5 saline or glucose to make the solution isotonic, bile salts, acacia, gelatin, sorbitan monoleate, polysorbate 80 (oleate esters of sorbitol and its anhydrides copolymerized with ethylene oxide) and the like.

10 The pharmaceutical composition comprising the oligonucleotide or the antibody can also be administered orally either in liquid or solid composition form. Compositions suitable for oral administration include solid forms, such as pills, capsules, granules, tablets,
15 and powders, and liquid forms, such as solutions, syrups, elixirs, and suspensions. Forms useful for parenteral administration include sterile solutions, emulsions, and suspensions.

20 Optimal dosages to be administered may be determined by those skilled in the art, and will vary with the particular inhibitor in use, the strength of the preparation, the mode of administration, and the advancement of the disease condition or abnormality.
25 Additional factors depending on the particular subject being treated will result in a need to adjust dosages, including subject age, weight, gender, diet, and time of administration.

30 This invention will be better understood from the Experimental Details which follow. However, one skilled in the art will readily appreciate that the specific

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methods and results discussed are merely illustrative of the invention as described more fully in the claims which follow thereafter.

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EXPERIMENTAL DETAILSFirst Series of Experiments

Molecular analysis of chromosomal translocations associated with multiple myeloma (MM) has indicated that the pathogenesis of this malignancy may be heterogeneous, being associated with several distinct oncogenes including BCL-1, MUM-1 and FGFR3. Structural abnormalities of chromosome 1q21, including translocations with chromosome 14q32, represent frequent cytogenetic aberrations associated with multiple myeloma. In order to identify the genes involved in these translocations, the breakpoint regions corresponding to both derivatives of a t(1;14)(q21;q32) detectable in the FR4 human plasmacytoma cell line were cloned. Analysis of the breakpoint sequences showed that they involved a reciprocal recombination between the Immunoglobulin heavy chain (IgH) locus on 14q32 and unknown sequences on 1q21. The normal locus corresponding to the 1q21 region involved in the translocation was cloned and the genes adjacent to the breakpoint region were identified by an exon-trapping strategy. Two genes were found, located within a 20 Kb distance from each other, in the region spanning the breakpoint on 1q21. The first gene, called MUM-2 (multiple myeloma-2) is expressed as a 2.5 Kb mRNA transcript detectable in spleen and lymph nodes. Cloning and sequencing of the full-length MUM-2cDNA predicts a 515 amino acid cell surface glycoprotein containing four extracellular Ig-type domains, a transmembrane and a cytoplasmic domain and sharing a 37% identity (51%homology) with Fc gamma receptor I over its first three extracellular domains. In FR4 cells, the

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translocation breakpoints interrupt the MUM-2 coding domain and juxtapose it to the IgH locus in the same transcriptional orientation. As a consequence, structurally abnormal FR4-specific MUM-2 transcripts (3.0, 5.2 and 6.0 Kb) in lymph nodes and spleen and encodes a protein with an extracellular domain containing six Ig-type domains homologous to members of the Fc gamma and Ig-type adhesion receptor families. The structure of the MUM-2 and MUM-3 genes and their direct involvement in a MM-associated translocation suggest that these genes code for novel cell surface receptors important for normal lymphocyte function and B cell malignancy.

Second Series of Experiments

15 Experimental Procedures

Cell Lines

The MM cell lines used in this study (FR4, U266, JJN3, EJM, SKMM1, RPMI-8226, XG1, XG2, XG4, XG6, XG7) have been previously reported (Tagawa et al., 1990), (Jernberg et al., 1987), (Hamilton et al., 1990; Jackson et al., 1989), (Eton et al., 1989), (Zhang et al., 1994). The FR4 cell line was established in the laboratory of one of the authors (S.T). The U266, JJN3, and EJM cell lines were gifts from Dr. K. Nilsson (University of Uppsala, Uppsala, Sweden) and the SKMM-1 cell line was a gift of A.N. Houghton (Memorial Sloan Kettering Cancer Center, New York, NY). The five XG cell lines were obtained from Dr. Bernard Klein and cultured in the presence of 1 ng/ml human recombinant IL-6 as described previously (Zhang et al., 1994). The BL cell lines with 1q21 abnormalities

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have been previously described (Polito et al., 1995), (Magrath et al., 1980) and were grown in RPMI, 10% FCS.

Genomic and cDNA library screening and DNA sequence analysis

Two genomic libraries were constructed from FR4 genomic DNA either by BamHI complete digestion or by Sau3AI partial digestion and subsequent ligation of gel-purified fractions into the LDASH-II phage vector (Stratagene). The BamHI library was screened with a 4.2 kb XhoI-BamHI probe derived from the Ca locus and the Sau3AI library was screened with a 5'Sa probe previously described (Bergsagel et al., 1996). A human placental DNA library (Stratagene) was screened with probe 1.0EH (Figures 8A-8C) to obtain the germline 1q21 locus. Library screening and plaque isolation were preformed according to established procedures (Sambrook et al., 1989). *IRTA1* and *IRTA2* cDNA clones were isolated from an oligo-dT/random-primed cDNA library constructed from normal human spleen RNA (Clontech). The *IRTA1* cDNA probe used for library screening was obtained from RT-PCR of human spleen cDNA using primers flanking exons 1 and 3. DNA sequencing was preformed on an ABI 373 automated sequencer (Applied Biosystems). Sequence homology searches were carried out through the BLAST e-mail server at the National Center for Biotechnology Information, Bethesda, MD.

PAC and YAC isolation and exon trapping

Human PAC clones were obtained by screening a human PAC library spotted onto nylon membranes (Research Genetics), with the 1.0 EH probe (Figures 8A-8C). The Zeneca

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(formerly ICI) human YAC library (Anand et al., 1990) obtained from the United Kingdom Human Genome Mapping Resource Center (UK-HGMP) was screened using a PCR-based pooling strategy. Exon trapping was performed using the
5 exon trapping system (Gibco BRL), according to the manufacturer's instructions.

Isolation of PAC/YAC end clones, pulsed-field gel electrophoresis (PFGE) and fluorescence in situ
10 hybridization (FISH) analysis

PAC DNA extraction was performed according to standard alkaline lysis methods (Drakopoli N et al., 1996). A vectorette-PCR method was used to isolate PAC and YAC end
15 probes (Riley et al., 1990), as previously described (Iida et al, 1996). PFGE analysis was performed according to standard protocols (Drakopoli N et al., 1996) using the CHEF Mapper system (BioRad, Hercules, CA). Biotin labeling of PAC DNA, chromosome preparation and FISH were
20 performed as previously described (Rao et al., 1993).

Southern and Northern blot analyses, RACE and RT-PCR

Southern and northern blot analyses were performed as described previously (Neri et al, 1991). For Northern
25 blot analyses total RNA was prepared by the guanidium thiocyanate method and poly(A) RNA was selected using poly(T)-coated beads (Oligotex Kit by Quigen). For Northern blots, 2 mg of poly(A) RNA were loaded per lane. Multiple tissue Northern filters were obtained from
30 Clontech. RACE was performed using the Marathon cDNA Amplification kit (Clontech) and Marathon-Ready spleen

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CDNA. First strand cDNA synthesis was performed using the Superscript RT-PCR system (Gibco BRL)

In situ hybridization

5 Digoxigenin-containing antisense and sense cRNA probes were transcribed with T3 and T7 RNA polymerase, respectively, from linearized pBluescript KS+ plasmids containing coding region of cDNAs (nucleotides 62 to 1681 of IRTA1 and 18 to 2996 of IRTA2.) Hyperplastic human tonsillar tissue surgically resected from^{www} children in
10 Babies' Hospital, Columbia Presbyterian Medical Center was snap frozen in powdered dry ice. Cryostat sections were stored for several days at -80 degrees C prior to processing. Non-radioactive *in situ* hybridization was
15 performed essentially as described (Frank et al., 1999), except that fixation time in 4% paraformaldehyde was increased to 20 minutes, and proteinase K treatment was omitted. The stringency of hybridization was 68 degrees C, in 5X SSC, 50% formamide. Alkaline phosphatase-
20 conjugated anti-digoxigenin antibody staining was developed with BCIP/NBT substrate.

Transfection, immunoprecipitation and Western Blotting

293 cells (ATCC), grown in DMEM, 10% FCS were transiently
25 transfected, according to the standard calcium phosphate method, with pMT2T and pMT2T-IRTA1/Ca transient expression constructs. The latter was generated using the IRTA1/Ca RT-PCR product from FR4. Cells (2×10^6 of transfectants and 2×10^7 of remaining cell lines) were
30 solubilized in Triton X-100 lysis buffer (150 mM NaCl, 10 mM Tris-HCl [pH 7.4], 1% Tx-100, 0.1% BSA) in the presence of a protease inhibitors cocktail (Roche Biochemicals).

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Lysates were incubated at 4°C for 2 hours with 4 mg/ml of the monoclonal antibody #117-332-1 (Yu et al., 1990) (Tanox Biosystems, Inc, Houston, Texas) that was raised against the extracellular portion of the IgA membrane peptide. Immune complexes were isolated with protein G-Sepharose (Pharmacia) prior to electrophoresis on 10-20% Tris-HCl gradient gels (Biorad) and immunoblotting, using 15 mg/ml of the #117-332-1 antibody. Results were visualized by ECL (Amersham).

RESULTS

Molecular Cloning of the t(1;14)(q21;q32)

Chromosomal translocations involving the Ig heavy-chain (IGH) locus often occur within or near IgH switch regions as a result of "illegitimate" switch recombination events (Dalla-Favera et al., 1983; Chesi et al., 1996; Chesi et al., 1998). The breakpoints can be detected by Southern-blot hybridization assays as rearranged alleles in which the IGH constant (C_H) region sequences have lost their syntenic association with IGH joining (J_H) and 5' switch region (S) sequences (Dalla-Favera et al., 1983; Neri et al., 1988; Neri et al., 1991; Bergsagel et al., 1996). This assay has led to the identification of several chromosomal partners for the IgH locus in B-NHL and MM (Taub et al., 1982; Dalla-Favera et al., 1983; Neri et al., 1988; Neri et al., 1991; Ye et al., 1993; Chesi et al., 1996; Richelda et al., 1997; Iida et al., 1997; Dyomin et al., 1997; Dyomin et al., 2000). We employed the same strategy in order to clone the 1q21 breakpoint region in FR4, a myeloma cell line carrying a t(1;14)(q21;q32), as determined by cytogenetic analysis

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(Tagawa et al., 1990; Taniwaki M, unpublished results). Two "illegitimately" rearranged fragments were identified within the C α heavy-chain locus in FR4 by Southern blot hybridization analysis (data not shown), and were cloned from phage libraries constructed from FR4 genomic DNA. Restriction mapping, Southern blot hybridization and partial nucleotide sequencing of two genomic phages (clones λ FR4B-5 and λ FR4S-a, Figure 8A) demonstrated that they contained the chromosomal breakpoints of a reciprocal balanced translocation between the C α_1 locus on 14q32 and non-IGH sequences. A probe (1.0EH) representing these non-IgH sequences (Figure 8A) was then used to clone the corresponding normal genomic locus from phage, P1 artificial chromosome (PAC), and yeast artificial chromosome (YAC) human genomic libraries. Fluorescence in situ hybridization (FISH) analysis of normal human metaphase spreads using the 100-kb non-chimaeric PAC clone 49A16 which spans the breakpoint region (see below, Figure 13), identified the partner chromosomal locus as derived from band 1q21 (Figure 8C). Mapping to a single locus within chromosome 1 was confirmed by hybridization of two non-repetitive probes to DNA from a somatic-cell hybrid panel representative of individual human chromosomes (data not shown). These results were consistent with the cloning of sequences spanning the t(1;14)(q21;q32) in FR4.

Sequence analysis of the breakpoint regions on the derivative chromosomes and alignment with the germline 14q32 and 1q21 loci revealed that the breakpoint had occurred in the intron between the CH3 and the

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transmembrane exon of $C\alpha_1$ on chromosome 14. Although the breakpoint region was devoid of recombination signal sequences (RSS) or switch signal sequences (Kuppers et al., 1999), the sequence CTTAAC (underlined on Figure 8B) was present in both germline chromosomes 14 and 1 at the breakpoint junction. One copy of this sequence was present in each of the derivative chromosomes, with a slight modification in the der(1) copy (point mutation in the last nucleotide: C to G). The nucleotides AT preceding CTTAAC on chromosome 1 were also present in both derivative chromosomes (Figure 8B). The translocation did not result in any loss of chromosome 1 sequences. On the other hand, in the chromosome 14 portion of der(1) we observed two deletions upstream of the breakpoint junction: a 16 nucleotide deletion (GGCACCTCCCCTTAAC) and a 4 nucleotide deletion (TGCA) 6 nucleotides upstream (Figure 8B). These observations indicate that the t(1;14)(q21;q32) in FR4 cells represents a balanced reciprocal translocation possibly facilitated by the presence of homologous sequences (CTTAAC) on both chromosomes.

The 1q21 breakpoint region contains genes coding for novel members of the Immunoglobulin Receptor Superfamily

25

We next investigated whether the region of chromosome 1q21 spanning the translocation breakpoint in FR4 contains a transcriptional unit. DNA from partially overlapping PAC clones 49A16 and 210K22 (Figure 13) was "shotgun" cloned in plasmids, sequenced and analyzed for homology to known genes in human genome databases. In parallel, candidate

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genes on the 49A16 PAC were sought by an exon trapping strategy (Church et al., 1994).

Mapping of the candidate exons on the 1q21 genomic clones revealed that the FR4 breakpoint had occurred between two trapped exons (see below, Figure 13), which belonged to the same transcript since they could be linked by RT-PCR using spleen RNA. This RT-PCR product was then used as a probe to screen a spleen cDNA library in order to isolate full-length clones corresponding to this transcript. Two sets of cDNA clones were identified, belonging to two distinct transcripts and sharing a 76% mRNA sequence identity within the 443 bp probe region. Full length cDNA clones for both transcripts were obtained by rapid amplification of cDNA ends (RACE) on human spleen cDNA that generated 5' and 3' extension products.

The schematic structure of the cDNA representing the first transcript is depicted in Figure 9A. Alternate usage of three potential polyadenylation sites in its 3' untranslated region gives rise to three mRNA species of 2.6, 2.7 and 3.5 kb, encoding the same putative 515-amino acid protein (Figure 9A). The predicted features of this protein include a signal peptide, in accordance with the [-3, -1] rule (von Heijne, 1986), four extracellular Ig-type domains carrying three potential asparagine (N)-linked glycosylation sites (Figure 9A), a 16 amino acid transmembrane and a 106 amino acid cytoplasmic domain with three putative consensus Src-homology 2 (SH2)-binding domains (Unkeless and Jin, 1997) (Figure 10B). These (SH2)-binding domains exhibit features of both ITAM (Immune-receptor Tyrosine-based Activation Motif

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-D/EX₇D/EX₂YXXL/IX₆₋₈YXXL/I; where X denotes non-conserved residues) (Reth, 1989) and ITIM motifs (Immune-receptor Tyrosine-based Inhibition Motif - S/V/L/IYXXL/V where X denotes non-conserved residues) (Unkeless and Jin, 1997).

5 As shown in Figure 10B, the first two SH2-binding domains are spaced 8 aminoacids apart, consistent with the consensus ITAM motif. Diverging from the consensus, the glutamate residue (E) is positioned four rather than two aminoacids before the first tyrosine (Y) (Figure 10B), and

10 the +3 position relative to tyrosine (Y) is occupied by valine (V) rather than leucine (L) or isoleucine (I) (Cambier, 1995). All three domains conform to the ITIM consensus and each is encoded by a separate exon, as is the case for ITIM. Thus their arrangement may give rise

15 to three ITIM or possibly to one ITAM and one ITIM. The overall structure of this protein suggests that it represents a novel transmembrane receptor of the Ig superfamily and it was therefore name IRTA1 (Immune Receptor Translocation Associated gene 1).

20

The second cDNA shares homology to IRTA1 (68% nucleotide identity for the length of the IRTA1 message encoding its extracellular domain) and was named IRTA2. The IRTA2 locus is more complex than IRTA1 and is transcribed into

25 three major mRNA isoforms (IRTA2a, IRTA2b, IRTA2c) of different molecular weight (2.8, 4.7 and 5.4 kb respectively), each with its own unique 3' untranslated region (Figure 9B). In addition, a 0.6 kb transcript (Figure 12A) arises from the usage of an early

30 polyadenylation signal at nucleotide 536 of IRTA2. The three predicted IRTA2 protein isoforms encoded by these

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transcripts share a common aminoacid sequence until residue 560, featuring a common signal peptide and six extracellular Ig-type domains (Figure 9B). IRTA2a encodes for a 759 aa secreted glycoprotein with eight Ig-type domains followed by 13 unique, predominantly polar aminoacids at its C-terminus. IRTA2b diverges from IRTA2a at amino acid residue 560, and extends for a short stretch of 32 additional residues, whose hydrophobicity is compatible with its docking to the plasma membrane via a GPI-anchor (Ferguson and Williams, 1988). IRTA2c is the longest isoform whose sequence deviates from IRTA2a at aminoacid 746. It encodes a 977 aa type I transmembrane glycoprotein with nine extracellular Ig-type domains, harboring eight potential N-linked glycosylation sites, a 23 aminoacid transmembrane and a 104 aminoacid cytoplasmic domain with three consensus SH2-binding motifs (Figure 10B). Each of the SH2-binding sites in IRTA2c agrees with the ITIM consensus (Figure 10B) and is encoded by a separate exon. These features suggest that IRTA2c is a novel transmembrane receptor of the Ig superfamily with secreted and GPI-linked isoforms.

Homology between the IRTA proteins and Immunoglobulin Superfamily Receptors

25

Amino acid alignment of the entire extracellular domains of the IRTA1 and IRTA2 proteins to each other and to other Ig superfamily members revealed a remarkable homology between them (47% identity and 51% similarity) and a lower, but striking homology to the Fc gamma receptor family of proteins. This homology was stronger in the aminoacid positions conserved among the different classes

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of Fc receptors. Among Fc receptors, the high affinity IgG receptor FCGRI (CD64) shared the highest levels of homology with the first three Ig-domains of IRTA1 and IRTA2 (37% identity and 50% similarity) throughout its entire extracellular portion (Figure 10A). Lower levels of homology were observed between the IRTA proteins and the extracellular domains of other cell surface molecules, including human platelet endothelial cell adhesion molecule (PECAM1), B-lymphocyte cell adhesion molecule (CD22) and Biliary Glycoprotein 1 (BGP1) (22-25% identity, 38-41% homology).

No homology is apparent between the IRTAs and members of the Fc receptor family in their cytoplasmic domains. In contrast, significant aminoacid homology is present between IRTA1 and PECAM1 (31% aminoacid identity and 45% homology), IRTA2c and BGP1 (30% identity, 35% homology) and IRTA2c and PECAM1 (28% identity, 50% homology) (Figure 10B). These homologies suggest employment of similar downstream signaling pathways by these different proteins.

IRTA1 and IRTA2 are normally expressed in specific subpopulations of B cells

The normal expression pattern of the IRTA1 and IRTA2 mRNAs was first analyzed by Northern blot hybridization of RNA derived from different normal human tissues and from human cell lines representing different hematopoietic lineages and stages of B-cell development.

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IRTA1 expression was detected at a very low level in human spleen and lymph node RNA (Figure 11A, left panel) and was undetectable in all other human tissues analyzed, including fetal liver, bone marrow, lung, placenta, small intestine, kidney, liver, colon, skeletal muscle, heart and brain (data not shown). Among B cell lines, IRTA1 expression was absent in cell lines representing pre-B and germinal center B-cells, plasma cells and cells of erythroid, T-cell and myeloid origin (data not shown, see Materials and Methods). Expression was detectable at very low levels only in EBV-immortalized lymphoblastoid cell lines (LCL), which represent a subpopulation (immunoblasts) positioned downstream of germinal center B cells in B-cell differentiation. However, expression was induced in estrogen-deprived ER/EB cells which, being immortalized by a recombinant EBV genome in which the EBNA2 gene is fused to the estrogen receptor, proliferate in the presence of estrogen while they arrest in the G₀/G₁ phase upon estrogen deprivation (Kempkes et al., 1995). IRTA1 expression was barely detectable in these cells in the presence of estrogen, but was induced (10-fold) upon their G₀/G₁ arrest following estrogen withdrawal (Figure 11A, right panel). Taken together, these results suggest that IRTA1 is expressed in a lymphoid subpopulation present in spleen and lymph nodes and presumably represented by resting B cells.

To further investigate the phenotype and tissue distribution of the cells expressing IRTA1, we performed *in situ* hybridization on human tonsillar tissue using a IRTA1 antisense cDNA probe (Figure 11B). Serial sections were processed for *in situ* hybridization with a control

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sense cDNA probe (Panel # 1 in Figure 11B), an antisense cDNA probe (Panel # 2) and hematoxylin and eosin (H&E) staining (Panel # 3) to outline the architecture of the lymphoid tissue. The *IRTA1* hybridization signal was excluded from the germinal center and the mantle zone of the follicles and was characteristically concentrated in the perifollicular zone with infiltrations in the intra-epithelial region (Figures 11B-2, 11B-4). In this region, only B cells were positive as documented by staining with B cell specific markers (IgD, not shown), and by immunohistochemical analysis with anti-*IRTA1* and anti-B (CD20, PAX5), anti-T (CD3), and anti-monocyte (CD68) antibodies (not shown; G. Cattoretti et al., manuscript in preparation). This perifollicular area is the "marginal zone" equivalent of the tonsil, representing a functionally distinct B-cell compartment that contains mostly memory B-cells and monocytoïd B-cells (de Wolf-Peeters et al., 1997). Together with the Northern blot analysis of normal tissues and cell lines, these results indicate that *IRTA1* is expressed in a subpopulation of resting mature B-cells topographically located in the perifollicular and intraepithelial region, sites rich in memory B cells.

In the case of *IRTA2*, Northern blot analysis detected all alternatively spliced species in human lymph node, spleen, bone marrow and small intestine mRNA, with relative preponderance of the *IRTA2a* isoform (Figure 12A, left panel). Among the hematopoietic cell lines of lymphoid and non-lymphoid origin tested, *IRTA2* expression was restricted to B-cell lines with an immunoblastic, post-germinal center phenotype (Figure 12A, right panel). Similarly to *IRTA1*, it was absent from cell lines derived

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from pre-B cells, germinal center centroblasts, plasma cells, T-cells, erythroid cells and myeloid cells (Figure 12A, right panel).

5 In situ hybridization analysis of human tonsillar tissue, using the *IRTA2c* cDNA as a probe, was consistent with the results of the Northern blot analysis. The *IRTA2* mRNA was largely excluded from the mantle zone of the germinal center, with the exception of a few positive cells
10 (Figures 12B-2, 12B4). Within the germinal center, the dark zone, represented by centroblasts, appeared negative for *IRTA2*, while the light zone, rich in centrocytes, was strongly positive (Figures 12B-2, 12B-4). Finally, *IRTA2* mRNA was detected in the "marginal zone" equivalent region
15 outside germinal center follicles and in the intraepithelial and interfollicular regions of the tonsil. This pattern is consistent with specificity of *IRTA2* for centrocytes and post-germinal center B cells. Comparing their expression patterns, we conclude that both are
20 specific for mature B cells, but *IRTA2* has a broader pattern of expression that includes centrocytes and interfollicular B cells, while *IRTA1* is restricted to marginal zone B cells, most likely memory cells.

25 Genomic organization of the *IRTA1* and *IRTA2* genes

To understand the consequences of 1q21 abnormalities on *IRTA1* and *IRTA2* gene structure and expression, we first determined the organization of their genomic loci. The *IRTA1* gene contains 11 exons with a total genomic size of 24.5 kb (Figure 13). The *IRTA2* locus was found to span a genomic region of approximately 40 kb (Figure 13). The three *IRTA2* alternatively spliced products share their

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first 8 exons, at which point *IRTA2b* does not utilize the next splicing site, and terminates by entering its 3'UTR region. *IRTA2a* and *2c* isoforms splice into exon 9, with *IRTA2a* entering into its 3'UTR after exon 11 and *IRTA2c* splicing into exon 12 and extending until exon 18 (Figure 13).

Based on sequencing data, we determined that the *IRTA1* and *IRTA2* genes are located 21 kb distant from each other, juxtaposed in the same transcriptional orientation (Figure 13) that extends from the telomere (5') towards the centromere (3'). At the 1q21 locus, they are tightly linked to each other as well as to three additional genes we recently cloned through their homology to the *IRTAS* (I.M, manuscript in preparation). All five genes are contiguous, covering a ~300 kb region at 1q21. This region is located at the interval between previously reported 1q21 breakpoints. Based on the distance between genomic clones harboring the respective genes on the Whitehead Institute Radiation Hybrid map, the *IRTA1-2* locus is estimated to lie approximately 0.8 Mb away from the *MUC1* locus towards the telomere (N.P, unpublished data; Dyomin et al., 2000; Gilles et al., 2000) and less than or equal to 7 Mb away from the *FCGR1IB* locus towards the centromere (N.P, unpublished data).

The t(1;14)(q21;q32) translocation generates an *IRTA1/Ca₁* fusion protein in the FR4 myeloma cell line

Comparative restriction and nucleotide sequence analysis of germline versus rearranged sequences from the *Ca₁* and *IRTA1* loci showed that the translocation had fused

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sequences within intron 2 of the *IRTA1* gene to the intronic sequences between the *CH3* and the transmembrane exon of *Ca₁* in the same transcriptional orientation (Figure 14A). This suggested that, if *IRTA1* sequences were expressed in the translocated locus, the intact donor site at the 3' border of the *IRTA1* exon and the intact acceptor site at the 5' of *Ca₁* could be used to generate a fusion *IRTA1/Ca₁* mRNA, and possibly a *IRTA1/Ca₁* fusion protein.

10 In order to test this prediction, we analyzed *IRTA1* mRNA expression in FR4 by Northern blot analysis using an *IRTA1* cDNA probe derived from exon 1 (Figure 14A). This probe detected a 0.8 kb message in FR4 that was absent from other B-cell lines, and was shorter than the normal 2.5 kb message detectable in ER/EB cells (Figure 14B). We cloned this transcript by RT-PCR of FR4 mRNA using primers derived from sequences at the 5' border of *IRTA1* exon 1 and the 3' border of the *Ca₁* cytoplasmic exon (Figure 14A). An RT-PCR product was obtained from FR4, but not from the DAKIKI cell line expressing wild-type surface IgA, or other cell lines lacking a t(1;14) translocation (data not shown). Direct sequencing analysis of the PCR product indicated that splicing had precisely linked *IRTA1* and *Ca₁* at canonical splicing sites and determined that the fusion transcript was 820 bp long.

30 Analysis of the predicted protein product indicated that the *IRTA1/Ca₁* splicing had resulted in a fusion between the *IRTA1* signal peptide and first two extracellular aminoacids, with the 32-amino acid long extracellular spacer, transmembrane domain and cytoplasmic tail of the

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membrane IgA₁ (mIgA₁) receptor (Figure 14C). To assay for the expression of this fusion protein in FR4 protein extracts, we used an antibody directed against extracellular aminoacid residues specific for the transmembrane isoform of Cα₁ (Yu et al., 1990) for immunoprecipitation, followed by Western blotting. Our results demonstrated that FR4 cells, but not a control cell line (DAKIKI) expressing wild-type surface IgA, express a 9.8kDa protein consistent with the predicted size of IRTA1/Cα₁ fusion protein (Figure 14D). These results show that the translocated allele encodes a fusion protein, composed of the signal peptide and first two extracellular residues of IRTA1 (17 aminoacids) fused to the Cα₁ encoded transmembrane and cytoplasmic domains (71 aminoacids). In contrast to IRTA1/Cα₁ overexpression on der(14), no expression was detected in FR4 for the reciprocal Cα₁/IRTA1 transcript or for the intact IRTA2 gene on der(1).

With the exception of FR4, IRTA1 mRNA expression was not detected in any other myeloma or lymphoma cell line, regardless of the status of its chromosomal band 1q21 (data not shown). Thus, the IRTA1/Cα fusion represents a rare event in 1q21 aberrations.

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Frequent deregulation of IRTA2 expression in cell lines carrying 1q21 abnormalities

In order to establish the physical relationship between other 1q21 breakpoints and the IRTA1/2 locus, we performed FISH analysis with the PAC 49A16 on our panel of BL and MM cell lines. Among ten BL cell lines analyzed, seven with

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dup(1)(q21q32) and three with 1q21 translocations (AS283A, BL104, BL136), we detected three signals corresponding to the *IRTA1/IRTA2* locus in seven of the former and two of the latter, consistent with dup(1)(q21q32) in the first case and dup(1)(q21q32) followed by a translocation breakpoint at 1q21 in the second. (Table 1). FISH analysis of AS283A and BL136, using probes spanning the *IRTA* locus and with neighboring genomic clones, placed the breakpoint of the derivative chromosomes outside the *IRTA* locus in both cell lines, at a distance of >800 kb towards the centromere in AS283A and >800 kb towards the telomere in BL136 (N.P, unpublished results). Consistent with this finding, analysis of 30 cases of MM primary tumors by interphase FISH with the 300-kb YAC 23GC4 (Figure 13), showed that 15 cases (50% of total analyzed) had more than two interphase FISH signals (data not shown), while double color FISH with two PAC clones flanking the YAC centromeric and telomeric borders detected no split of these two probes in any of the cases. These results indicate that, with the exception of FR4, the breakpoints of 1q21 aberrations in BL or MM are not within or in close proximity to the genomic region defined by *IRTA1* and *IRTA2*. However, the consistent outcome of either dup(1)(q21q32) (see Table 1) or dup(1)(q21q32) followed by unbalanced translocations (AS283A, BL136, XG2, XG7 in Table 1) is partial trisomy or tetrasomy of the region of 1q21 containing the *IRTA* genes.

Table 1. Summary of karyotypic and FISH data on IRTA1/IRTA2 locus

Turnour type	Cytogenetics	PAC 49A16	Copy number of IRTA locus by FISH	IRTA2 mRNA expression
Burkitt Lymphoma				
AS283A	der(4) t(1;4)(q21;q35)	der(4), normal 1	3	++++++
MC116	dup1q21	dup1q21	3	+++
CA46	dup1q21	dup1q21	3	+++
PA682	dup1q21	dup1q21	3	++
BrgIgA	dup1q21	dup1q21	3	++
BL32	dup1q21	dup1q21	3	-
BL92	dup1q21	dup1q21	3	++
BL103	invdup1q21	dup1q21	3	+
BL104	t(1;3)(q21;p25)	der(1)	2	+
BL136	der(1)(qter1q21::q21)	der(1)	3	++
Multiple Myeloma				
XG2	der(1) t(1;?)(q21;?) der 19 t(1;19)(q12;?)	der(1), normal 1 der(19)	3	++++
XG7	der(9) t(1;9)(q12;?) der(19) t(1;19)(q12;?) der(1) t(1;?)(q21;?) x2	der(9) der(19) der(1) x2	4	-

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We then investigated whether these aberrations had an effect on *IRTA2* mRNA expression. To this end, we used a cDNA probe corresponding to the *IRTA2* 5' untranslated region to screen a Northern blot with a panel of B-NHL and MM cell lines lacking or displaying 1q21 chromosomal abnormalities. The results show that most (ten out of twelve) BL lines with normal 1q21 chromosomes essentially lack *IRTA2* expression, consistent with the fact that BL derive from GC centroblasts which normally lack *IRTA2* expression (Figure 15A, left panel). In contrast, most BL lines carrying 1q21 abnormalities (ten out of twelve) clearly display *IRTA2* mRNA upregulation (Figure 15A, right panel), ranging from 2 to 50 fold over baseline levels detected in BL with normal 1q21. Among myeloma cell lines, *IRTA2* was overexpressed in one out of three lines displaying 1q21 abnormalities (XG2), while it was expressed in none out of seven with normal 1q21 (Figure 15B).

These results show a strong correlation between the presence of 1q21 chromosomal aberrations and deregulation of *IRTA2* mRNA expression in BL and suggest that trisomies of the *IRTA2* locus may deregulate its expression in this lymphoma subtype (see Discussion).

25

Discussion

Efforts described herein to identify genes involved in chromosomal aberrations affecting band 1q21 in Multiple myeloma and B cell lymphoma, led to the discovery of *IRTA1* and *IRTA2*, two founding members of a novel subfamily of related receptors within the immunoreceptor family; full length nucleic acid sequences encoding *IRTA1* and *IRTA2*

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proteins are provided herein, as are the amino acid sequences of the encoded IRTA1 and IRTA2 proteins. Subsequently three additional genes of members of this subfamily of related receptors were isolated, IRTA3, IRTA4, and IRTA5, the full length nucleic acid sequences of which are provided herein, as are the amino acid sequences of the encoded IRTA3, IRTA4, and IRTA5 proteins. These results have implications for the normal biology of B cells as well as for the role of 1q21 aberrations in lymphomagenesis.

IRTA1 and IRTA2 are founding members of a new subfamily within the Ig superfamily

Several features shared between the two IRTA genes and their encoded proteins suggest that they form a new subfamily within the immunoreceptor superfamily. First, they share a higher degree of homology with each other in their extracellular domains than with other superfamily members both in their mRNA (68% identity) and protein (47% identity) sequence. Second, they share homology in their cytoplasmic domains, marked by the presence of ITAM-like and ITIM signaling motifs in the context of homologous aminoacid sequences. Third, IRTA1 and IRTA2 belong to a larger subfamily of five genes displaying higher intrafamily homology and tight clustering within a ~300 kb region at 1q21 (I.M. et al., manuscript in preparation). Their genomic organization suggests that a common ancestral gene may have given rise to this subfamily, by a process of duplication and sequence divergence, similar to the mechanism proposed for the Fc receptor family (Qiu et al., 1990).

In their extracellular domain, the IRTA proteins are closely related to the Fc receptor subfamily based on the high degree of aminoacid homology shared especially with the high affinity FCGR1 receptor (37-45% aminoacid

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identity). A common evolutionary origin with Fc receptors is also suggested by the position of the *IRTA* family locus in the interval between the *FCGRI* locus on 1q21 and the *FCERI* and *FCGRII-III* loci on 1q21-q23. Finally, the *IRTA* and *FCR* genes share a similar exon/intron organization of the gene portion that encodes their signal peptide, in particular the two 5' leader exons with the sequences encoding the signal peptidase site located within the second 21-bp exon.

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Based on their cytoplasmic ITIM-like motifs, the *IRTA* proteins can be considered members of the Inhibitory Receptor Superfamily (IRS), a group of receptors that block activation of many cell types in the immune system (Lanier, 1998). Such members include *FCGRIIB* and *CD22* in the human (DeLisser et al., 1994) and *PIR-B* in the mouse (Kubagawa et al., 1997). Analogous to IRS members, the ITIM of *IRTA1* and *IRTA2* are encoded by individual exons. A feature that many IRS members share is the existence of corresponding activating receptor isoforms whose cytoplasmic domains are devoid of ITIM (reviewed in Ravetch and Lanier, 1998). It is possible that the secreted isoform of *IRTA2*, which lacks ITIM-like motifs, fulfills an analogous role by counteracting the effect of the transmembrane isoform.

25

Significant homology in the sequence and overall organization of their extracellular portion is shared among the *IRTA1* and *IRTA2* proteins and the Cell Adhesion Molecule (CAM) subfamily members *PECAM1*, *CD22* and *BGP1*. In addition, the ability of *IRTA2* to generate three protein isoforms with distinct subcellular localization (a transmembrane, a GPI-linked or a secreted protein) by differential splicing is shared by *NCAM*, another member of the CAM subfamily (Dickson et al., 1987; Gower et al., 1988). Thus, the *IRTA* family is also related to the CAM family, as has been previously suggested for a member of the Fc receptor family (murine *FCGRII*) because of its

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homology to PECAM1 (CAM, IRS family) (Daeron, 1991; Newman et al., 1990; Stockinger et al., 1990).

In conclusion, the IRTA family may represent an intersection among the Fc, IRS and CAM families, combining features from all three. Accordingly, IRTA proteins may have a role in the regulation of signal transduction during an immune response (like Fc receptors), intercellular communication (like members of the IRS and CAM families) and cell migration (like CAM family members) (DeLisser et al., 1994; Ravetch and Lanier, 2000). Initial experiments indicate that IRTA1 can weakly bind heat aggregated IgA, while IRTA2c can specifically bind heat aggregated human serum IgG (with higher affinity for IgG₁ and IgG₂), but not monomeric human IgG, IgA, IgM and IgE (data not shown). These initial data lend support to a functional relationship between the IRTA and the Fc receptor families, but do not exclude functions dependent on other ligands for the IRTA proteins.

Differential pattern of expression of IRTA genes in mature B cells

The IRTA genes display a specific pattern of expression in various normal B cell compartments. IRTA1 is topographically restricted to B cells within the perifollicular region, which was originally named marginal zone in the spleen, but is also detectable in most lymphoid organs (de Wolf-Peeters et al., 1997). The *in situ* hybridization data presented here have been confirmed by immunohistochemical analysis using anti-IRTA1 antibodies which show that the IRTA1 protein is selectively expressed in marginal zone B cells, and, among NHL, in marginal zone lymphoma, the tumors deriving from these cells (G. Cattoretti et al., manuscript in preparation). On the other hand, IRTA2 has a broader pattern of expression that includes GC centrocytes, as well as a broad spectrum of perifollicular cells, which

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may include immunoblasts and memory cells. Initial data suggest that the pattern of expression of IRTA3 is analogous to IRTA2, while IRTA4 and IRTA5 are selectively expressed in mantle zone B cells (I. Miller et al., manuscript in preparation), the pre-GC compartment of mature B cells (MacLennan, I. C., 1994). This topographic restriction of IRTA gene expression in lymphoid organs suggests that the IRTA molecules may play a role in the migration or activity of various B cell subpopulations in specific functional B cell compartments. In addition, IRTA expression should be useful for the differential diagnosis of NHL subtypes deriving from various B cell compartments, particularly IRTA1 in the diagnosis of marginal zone lymphoma.

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IRTA1 locus and 1q21 abnormalities in MM

In the FR4 cell line, the consequence of the t(1;14) translocation is the formation of an IRTA1/C α ₁ fusion gene. Despite the fact that this gene is driven by the IRTA1 promoter region, which is normally silent in plasma cells, its expression is high in FR4, presumably due to the influence of the C α ₁ 3' LCR, which is retained downstream of the C α ₁ locus. The fusion gene encodes a IRTA1/C α ₁ fusion protein which contains only the signal peptide and first two amino acids of IRTA1 linked to the surface IgA receptor. The latter has been almost completely deprived of its extracellular domain, but retains all its transmembrane and intracellular domains. This structure indicates that the IRTA1/C α ₁ fusion protein, though probably unable to bind any ligand, may retain the potential for dimerization and signaling. In particular, the membrane (m) IgA-derived extracellular portion contains a cysteine residue, which can be involved in disulphide bonds between two α -chains or between α -chains and associated proteins, such as the auxiliary surface receptor CD19 (Leduc et al., 1997). The fusion protein also carries the intact, 14 amino acid mIgA cytoplasmic

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domain, which is highly conserved in evolution (Reth, 1992) and may play an essential role in the proliferation, survival and differentiation of mature B-cells, analogous to the role of mIgG and mIgE (Kaisho et al., 1997). Thus, 5 the emergence of the IRTA1/Ca_v protein in FR4 may have provided the cells with a proliferative and survival advantage during tumor development through ligand (antigen)-independent activation of the BCR pathway. This fusion event however, appears to be rare in B-cell 10 malignancy, since so far we were able to detect it only in FR4 cells.

IRTA2 locus and 1q21 abnormalities in MM and BL

Abnormal expression of IRTA2 is a frequent consequence of 15 1q21 abnormalities. Although this gene is not expressed normally either in centroblasts, the presumed normal counterparts of BL (Kuppers et al., 1999), or in BL with normal 1q21, its levels are upregulated on average by 10-fold in BL cell lines with 1q21 abnormalities. This 20 deregulation appears to be specific for IRTA2 since all the other 4 IRTA genes present within 300 kb on 1q21 are either not expressed in BL (IRTA1), or their pattern of expression does not correlate with the presence of 1q21 abnormalities (IRTA3, 4, 5, not shown). The mechanism by 25 which this deregulation occurs is difficult to ascertain in the absence of structural lesions within or adjacent to the IRTA2 gene. Since the heterogeneous aberrations that affect 1q21 all cause an excess copy number of the IRTA locus, it is possible that this may lead to regulatory 30 disturbances, as is the case for low level amplification of BCL2 in FL lacking (14;18) translocations (Monni et al., 1997), REL in diffuse large cell lymphoma (Houldsworth et al., 1996; Rao et al., 1998) and deregulation of Cyclin D1 in some MM cases with trisomy 11 35 (Pruneri et al., 2000). On the other hand, 1q21 abnormalities, including translocations and duplications, change the genomic context of the IRTA locus and may lead

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to deregulation of *IRTA2* by distant cis-acting enhancer chromatin organizing elements acting on its promoter as is the case for *MYC* in endemic BL (Pelicci et al., 1986) and MM (Shou et al., 2000) and for *CCND1* in mantle cell lymphoma (Bosch et al., 1994; Swerdlow et al., 1995) and MM (Pruneri et al., 2000).

The biological consequences of deregulated *IRTA2* expression are difficult to predict at this stage. The observation that *IRTA2* has homology with CAM adhesion receptors, together with its specific distribution in the light zone of the GC suggest that its ectopic expression in centroblasts may cause a disruption in the GC development and architecture. On the other hand, our initial observations that *IRTA2* can bind IgG immune complexes comparably to bona fide Fc receptors suggest that its inappropriate expression may perturb the dynamics of cell surface regulation of B cell immunological responses, possibly leading to clonal expansion. Deregulated expression of *FCGR2B* as a result of the t(1;14)(q21;q32) in follicular lymphoma has been proposed to contribute to lymphomagenesis in this tumor type (Callanan et al., 2000), by a mechanism involving escape by tumor cells of anti-tumor immune surveillance through their Fc binding and inactivation of tumor specific IgG. Similar evasion mechanisms have been observed in cells infected by Fc-encoding herpesviruses (Dubin et al., 1991). The role of *IRTA2* deregulation needs to be tested in "gain of function" transgenic mice constitutively expressing *IRTA2* in the GC.

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20 Third Series of Experiments

Chromosome 1q21 is frequently altered by translocations and duplications in several types of B cell malignancy, including multiple myeloma, Burkitt lymphoma, marginal
25 zone lymphomas, and follicular lymphoma. To identify the genes involved in these aberrations, cloned was the chromosomal breakpoint of a t(1;14)(q21;q32) in the myeloma cell line FR4. A 300kb region spanning the breakpoint contains at least five highly related adjacent
30 genes which encode surface receptor molecules that are members of the immunoglobulin gene superfamily, and thus called IRTA (Immunoglobulin Receptor Translocation

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Associated). The various IRTA molecules have from three to nine extracellular immunoglobulin superfamily domains and are related to the Fc gamma receptors. They have transmembrane and cytoplasmic domains containing ITIM-like and ITAM-like (ITRA-1, IRTA-3, IRTA-4) signaling motifs. In situ hybridization experiments show that all IRTA genes are expressed in the B cell lineage with distinct developmental stage-specific patterns: IRTA-1 is expressed in a marginal B cell pattern. IRTA-2 is expressed in centrocytes and more mature B cells. As a result of the translocation in FR4, IRTA-1 is broken and produces a fusion transcript with the immunoglobulin locus. The IRTA-2 gene, normally silent in centroblasts, is overexpressed in multiple myeloma and in Burkitt lymphoma cell lines carrying 1q21 abnormalities. The data here suggests that IRTA genes are novel B cell regulatory molecules that may also have a role in lymphomagenesis.

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What is claimed is:

1. An isolated nucleic acid molecule which encodes immunoglobulin receptor, Immunoglobulin superfamily
5 Receptor Translocation Associated, IRTA, protein.
2. The isolated nucleic acid molecule of claim 1,
wherein the IRTA protein is IRTA1 protein comprising
the amino acid sequence set forth in Figure 18A (SEQ
10 ID NO:1).
3. The isolated nucleic acid molecule of claim 1,
wherein the IRTA protein is IRTA2 protein comprising
the amino acid sequence set forth in Figures 18B-1-
15 18B-3 (SEQ ID NO:3).
4. The isolated nucleic acid molecule of claim 1,
wherein the IRTA protein is IRTA3 protein comprising
the amino acid sequence set forth in Figures 18C-1-
20 18C-2 (SEQ ID NO:5).
5. The isolated nucleic acid molecule of claim 1,
wherein the IRTA protein is IRTA4 protein comprising
the amino acid sequence set forth in Figures 18D-1-
25 18D-2 (SEQ ID NO: 7).
6. The isolated nucleic acid molecule of claim 1,
wherein the IRTA protein is IRTA5 protein comprising
the amino acid sequence set forth in Figures 18E-1-
30 18E-2 (SEQ ID NO: 9).

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7. An isolated nucleic acid molecule of claim 1, wherein the nucleic acid molecule is DNA.
8. The isolated DNA molecule of claim 2, wherein the DNA
5 is cDNA.
9. The isolated DNA molecule of claim 2, wherein the DNA is genomic DNA.
- 10 10. The isolated nucleic acid molecule of claim 1, wherein the nucleic acid molecule is an RNA molecule.
11. The isolated DNA molecule of claim 2, wherein the DNA molecule is cDNA having the nucleotide sequence set
15 forth in Figure 18A (SEQ ID NO:2).
12. The isolated DNA molecule of claim 2, wherein the DNA molecule is cDNA having the nucleotide sequence set forth in Figure 18A (SEQ ID NO:4).
- 20 13. The isolated DNA molecule of claim 2, wherein the DNA molecule is cDNA having the nucleotide sequence set forth in Figure 18A (SEQ ID NO:6).
- 25 14. The isolated DNA molecule of claim 2, wherein the DNA molecule is cDNA having the nucleotide sequence set forth in Figure 18A (SEQ ID NO:8).
- 30 15. The isolated DNA molecule of claim 2, wherein the DNA molecule is cDNA having the nucleotide sequence set forth in Figure 18A (SEQ ID NO:10).

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16. The isolated nucleic acid molecule of claim 1, wherein the nucleic acid molecule encodes a human IRTA1 protein.
- 5 17. The isolated nucleic acid molecule of claim 1 operatively linked to a promoter of DNA transcription.
- 10 18. The isolated nucleic acid molecule of claim 17, wherein the promoter comprises a bacterial, yeast, insect, plant or mammalian promoter.
- 15 19. A vector comprising the nucleic acid molecule of claim 17.
- 20 20. The vector of claim 19, wherein the vector is a plasmid.
21. A host cell comprising the vector of claim 20.
- 20 22. The host cell of claim 21, wherein the cell is selected from a group consisting of a bacterial cell, a plant cell, and insect cell and a mammalian cell.
- 25 23. An isolated nucleic acid molecule comprising at least 15 contiguous nucleotides capable of specifically hybridizing with a unique sequence included within the sequence of the isolated nucleic acid molecule encoding IRTA1 protein of claim 1.
- 30 24. The isolated nucleic acid molecule of claim 23 labeled with a detectable marker.

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25. The nucleic acid molecule of claim 24, wherein the detectable marker is selected from the group consisting of a radioactive isotope, enzyme, dye, biotin, a fluorescent label or a chemiluminescent label.
26. A method for detecting a B cell malignancy or a type of B cell malignancy in a sample from a subject wherein the B cell malignancy comprises a 1q21 chromosomal rearrangement which comprises:
- a) obtaining RNA from the sample from the subject;
 - b) contacting the RNA of step (a) with a nucleic acid molecule of at least 15 contiguous nucleotides capable of specifically hybridizing with a unique sequence included within the sequence of an isolated RNA encoding human IRTA protein selected from the group consisting of human IRTA1, IRTA2, IRTA3, IRTA4 and IRTA5, under conditions permitting hybridization of the RNA of step (a) with the nucleic acid molecule capable of specifically hybridizing with a unique sequence included within the sequence of an isolated RNA encoding human IRTA protein, wherein the nucleic acid molecule is labeled with a detectable marker; and
 - c) detecting any hybridization in step (b), wherein detection of hybridization indicates presence of B cell malignancy or a type of B cell malignancy in the sample.

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27. The method of claim 26, wherein the detectable marker is radioactive isotope, enzyme, dye, biotin, a fluorescent label or a chemiluminescent label.

5 28. The method of claim 26, wherein the B cell malignancy is selected from the group consisting of B cell lymphoma, multiple myeloma, Burkitt's lymphoma, marginal zone lymphoma, diffuse large cell lymphoma and follicular lymphoma cells.

10

29. The method of claim 28, wherein the B cell lymphoma is Mucosa-Associated-Lymphoid Tissue B cell lymphoma (MALT).

15 30. The method of claim 28, wherein the B cell lymphoma is non-Hodgkin's lymphoma.

31. An antisense oligonucleotide having a sequence capable of specifically hybridizing to an mRNA molecule encoding a human ITRA protein so as to prevent overexpression of the mRNA molecule.

20

32. The antisense oligonucleotide of claim 31, wherein the ITRA protein selected from the group consisting of human IRTA1, IRTA2, IRTA3, IRTA4 and IRTA5 protein.

25

33. A purified IRTA1 protein comprising the amino acid sequence set forth in Figure 18A (SEQ ID NO:1).

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34. The purified IRTA1 protein of claim 33, wherein the IRTA1 protein is human IRTA1.

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35. A purified IRTA2 protein comprising the amino acid sequence set forth in Figures 18B-1-18B-3 (SEQ ID NO:3).
- 5 36. The purified IRTA2 protein of claim 35, wherein the IRTA2 protein is human IRTA2.
37. A purified IRTA3 protein comprising the amino acid sequence set forth in Figures 18C-1-18C-2 (SEQ ID NO:5).
- 10 38. The purified IRTA3 protein of claim 37, wherein the IRTA3 protein is human IRTA3.
- 15 39. A purified IRTA4 protein comprising the amino acid sequence set forth in Figures 18D-1-18D-2 (SEQ ID NO: 7).
40. The purified IRTA3 protein of claim 39, wherein the IRTA4 protein is human IRTA4.
- 20 41. A purified IRTA5 protein comprising the amino acid sequence set forth in Figures 18E-1-18E-2 (SEQ ID NO: 9).
- 25 42. The purified IRTA5 protein of claim 41, wherein the IRTA5 protein is human IRTA5.
43. An antibody directed to a purified IRTA protein selected from the group consisting of human IRTA1, IRTA2, IRTA3, IRTA4 and IRTA5.
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44. The antibody of claim 43, wherein the IRTA protein is human IRTA protein.

5 45. The antibody of claim 43, wherein the antibody is a monoclonal antibody or a polyclonal antibody.

46. The antibody of claim 43, wherein the monoclonal antibody is a murine monoclonal antibody or a humanized monoclonal antibody.

10

47. The antibody of claim 43, wherein the antibody is conjugated to a therapeutic agent, wherein the therapeutic agent is selected from the group consisting of a radioisotope, a toxin, a toxoid, or a
15 chemotherapeutic agent.

48. A pharmaceutical composition comprising an amount of the antibody of claim 43 effective to bind to cancer cells expressing an IRTA protein selected from the
20 group consisting of human IRTA1, IRTA2, IRTA3, IRTA4 and IRTA5 so as to prevent growth of the cancer cells and a pharmaceutically acceptable carrier.

49. The pharmaceutical composition of claim 48, wherein
25 the cancer cells are selected from the group consisting of B cell lymphoma, a mantle cell lymphoma multiple myeloma, Burkitt's lymphoma, marginal zone lymphoma, diffuse large cell lymphoma and follicular lymphoma cells.

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50. The pharmaceutical composition of claim 49, wherein the B cell lymphoma cells are Mucosa-Associated-Lymphoid Tissue B cell lymphoma (MALT) cells.
- 5 51. The pharmaceutical composition of claim 49, wherein the B cell lymphoma cells are non-Hodgkin's lymphoma cells.
- 10 52. A pharmaceutical composition comprising an amount of the oligonucleotide of claim 31 effective to prevent overexpression of a human IRTA protein and a pharmaceutically acceptable carrier.
- 15 53. A method of diagnosing B cell malignancy which comprises a 1q21 chromosomal rearrangement in a sample from a subject which comprises:
- a) obtaining the sample from the subject;
 - b) contacting the sample of step (a) with the antibody of claim 43 capable of specifically binding with a human IRTA protein selected from the group consisting of human IRTA1, IRTA2, IRTA3, IRTA4 and IRTA5 IRTA protein on a cell surface of a cancer cell under conditions permitting binding of the antibody with human IRTA protein on the cell surface of the cancer cell, wherein the antibody is labeled with a detectable marker; and
 - c) detecting any binding in step (b), wherein detection of binding indicates a diagnosis of B cell malignancy in the sample.
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54. The method of claim 53, wherein the B cell malignancy is selected from the group consisting of B cell lymphoma, multiple myeloma, Burkitt's lymphoma, mantle cell lymphoma, marginal zone lymphoma, diffuse large cell lymphoma and follicular lymphoma.
55. The method of claim 54, wherein the B cell lymphoma is Mucosa-Associated-Lymphoid Tissue B cell lymphoma (MALT).
56. The method of claim 54, wherein the B cell lymphoma is non-Hodgkin's lymphoma.
57. A method of treating a subject having a B cell cancer which comprises administering to the subject an amount of anti-IRTA antibody effective to bind to cancer cells expressing an IRTA protein selected from the group consisting of human IRTA1, IRTA2, IRTA3, IRTA4 and IRTA5 so as to prevent growth of the cancer cells and a pharmaceutically acceptable carrier, thereby treating the subject.
58. The method of claim 57, wherein the anti-IRTA antibody is a monoclonal antibody.
59. The method of claim 58, wherein the monoclonal antibody is a murine monoclonal antibody or a humanized monoclonal antibody.
60. The method of claim 57, wherein the anti-IRTA antibody is a polyclonal antibody.

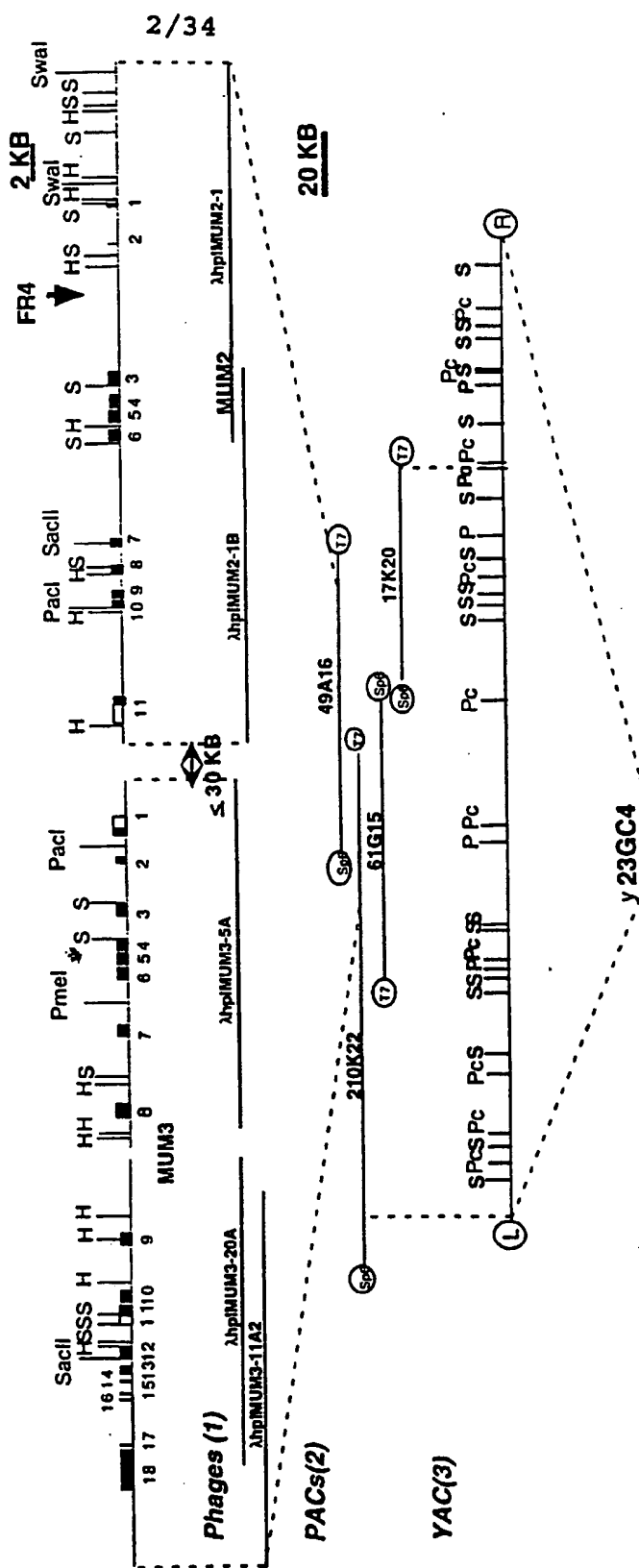
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61. The method of claim 57, wherein the B cell cancer is selected from the group consisting of B cell lymphoma, multiple myeloma, mantle cell lymphoma, Burkitt's lymphoma, marginal zone lymphoma, diffuse large cell lymphoma and follicular lymphoma.
62. The method of claim 61, wherein the B cell lymphoma is Mucosa-Associated-Lymphoid Tissue B cell lymphoma (MALT).
63. The method of claim 61, wherein the B cell lymphoma is non-Hodgkin's lymphoma.
64. A method of treating a subject having a B cell cancer which comprises administering to the subject an amount of the oligonucleotide of claim 31 effective to prevent overexpression of a human IRTA protein, so as to arrest cell growth or induce cell death of cancer cells expressing IRTA protein(s) and a pharmaceutically acceptable carrier, thereby treating the subject.
65. The method of claim 64, wherein the IRTA protein is selected from the group consisting of human IRTA1, IRTA2, IRTA3, IRTA4 and IRTA5 protein.
66. The method of claim 64, wherein the B cell cancer is selected from the group consisting of B cell lymphoma, mantle cell lymphoma, multiple myeloma, Burkitt's lymphoma, marginal zone lymphoma, diffuse large cell lymphoma and follicular lymphoma.

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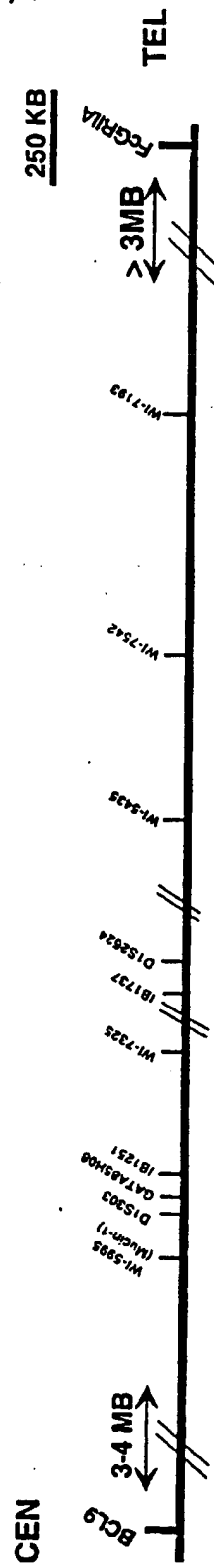
67. The method of claim 66, wherein the B cell lymphoma is Mucosa-Associated-Lymphoid Tissue B cell lymphoma (MALT).
- 5 68. The method of claim 66, wherein the B cell lymphoma is non-Hodgkin's lymphoma.

FIGURE 2A



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FIGURE 2B



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FIGURE 3

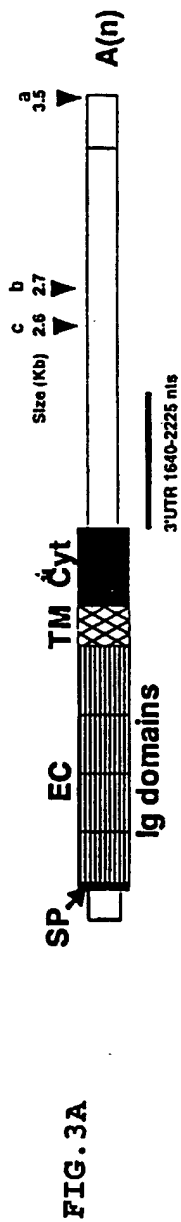


FIG. 3B

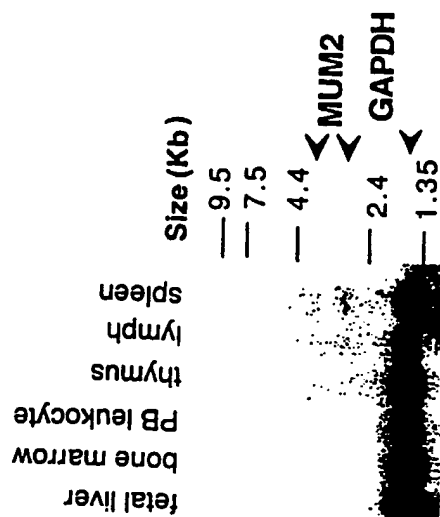


FIG. 3C

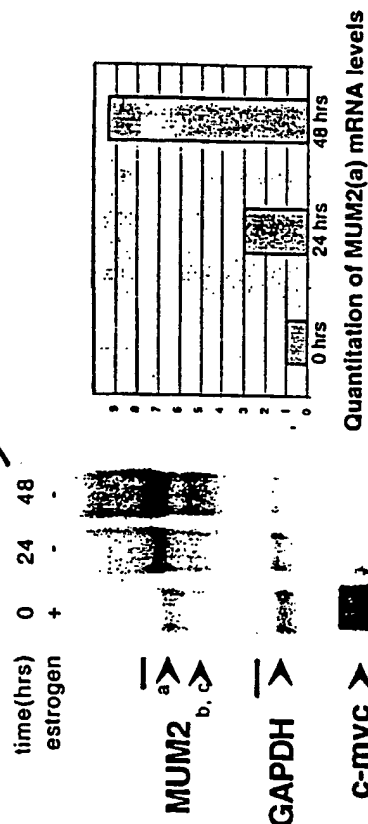


FIGURE 4

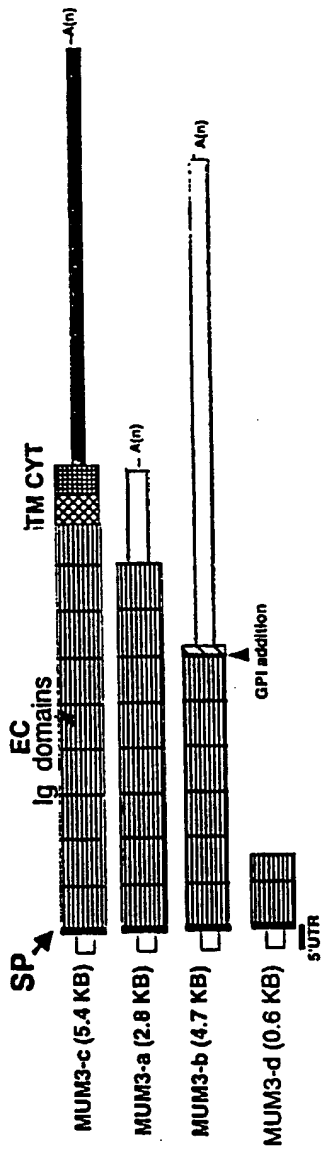
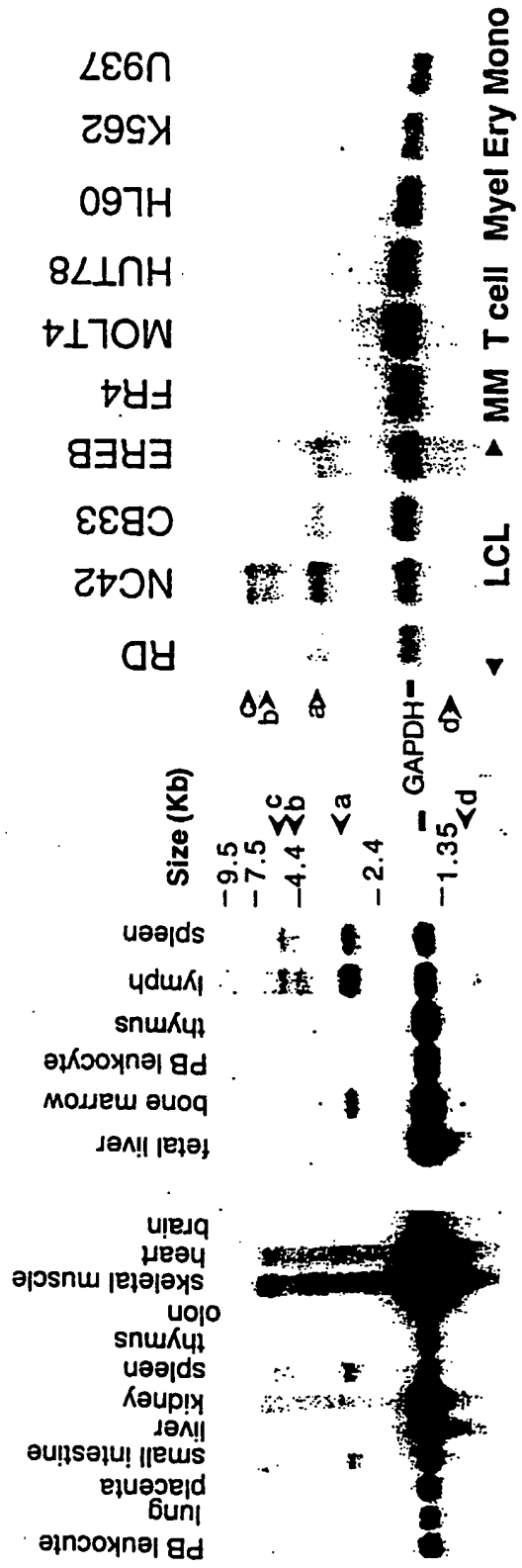


FIG. 4B



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FIGURE 5

1 CTCATACAGCTTTATGCAGAGAAGAAGCTTACTGAGCTCACTGCTGGTGTAGGCAAGTCTGCTTTGGCAA
M L L W A S
78 TCTGGGCTGACCTGGCTTGTCTCTCTCAGAACTCCTTCTCCAACCTGGAGCAGGCTTCCATGCTGCTGTGGGCGTCC
L L A F A P V C Q Q S A A A H K P V I S V H P P W T 32
155 TTGCTGGCCTTTGCTCCAGTCTGTGGACAATCTGCAGCTGCACACAAACCTGTGATTTCCGTCCATCCTCCATGGAC
T F F K G E R V T L T C N G F Q F Y A T E K T T W Y 58
232 CACATTCTTCAAAGGAGAGAGAGTGAATCTGACTTGAATGATTTTCACTTCTATGCAACAGAGAAAACAACATGGT
H R H Y W G E K L T L T P G N T L E V R E S G L Y 83
309 ATCATCGGCACTACTGGGAGAAAAGTTGACCTGACCCAGGAAACACCTCGAGGTTCCGGGAATCTGGACTGTAC
R C Q A R G S P R S N P V R L L F S S D S L I L Q A 109
386 AGATGCCAGGCCCCGGGCTCCCCACGAAGTAACCTGTGCGCTTGTCTTTTCTTCAGACTCCTTAATCTGCAGGC
P Y S V F E G D T L V L R C H R R R K E K L T A V K 135
463 ACCATATTCTGTGTTGAAGGTGACACATTGGTTCTGAGATGCCACAGAAGAAGGAAAGAGAAATTGACTGCTGTGA
Y T W N G N I L S I S N K S W D L L I P Q A S S N 160
540 AATATACTTGAATGGAACATTCTTTCCATTCTAATAAAGCTGGGATCTTCTTATCCCAAGCAAGTTCAAAT
N N G N Y R C I G Y G D E N D V F R S N F K I I K I 186
617 AACAAATGGCAATTATCGATGCATTGGATATGGAGATGAGAATGATGATTTAGATCAAATTTCAAATAATTAAAT
Q E L F P H P E L K A T D S Q P T E G N S V N L S C 212
694 TCAAGAACTATTTCCACATCCAGAGCTGAAAGCTACAGACTCTCAGCCTACAGAGGGGAATCTGTAAACCTGAGCT
E T Q L P P P E R S D T L P H F N F F R D G E V I L 237
771 GTGAAACACAGCTTCTCCAGAGCGGTGACACACCCCACTTCACTTCACTTCTTCAGAGATGGCGAGGTCATCTG
S D W S T Y P E L Q L P T V W R E N S G S Y W C G A 263
848 TCAGACTGGAGCAGTACCCGGAACCTCAGCTCCCAACCGTCTGGAGAGAAAACCTCAGGATCCTATTGGTGTGGTGC
E T V R G N I H K H S P S L Q I H V Q R I P V S I L 289
925 TGAACAGTGAAGGGTAACATCCACAAGCAGTCCCTCGCTACAGATCCATGTGCAGCGGATCCCTGTGTCTGGGG
L L E T Q P S G G Q A V E G E M L V L V C S V A E 314
1002 TGCTCTGGAGACCCAGCCCTCAGGGGGCAGGCTGTGAAGGGGAGATGCTGGTCTTGTCTGCTCCGTGGCTGAA
G T G D T T F S W H R E D M Q E S L G R K T V I L 340
1079 GGCACAGGGGATACCACATTCTCTGGCACCGAGAGGACATGCAGGAGAGTCTGGGGAGGAAAACCTCAGCGTCCCT
R A E L E L P A I R Q S H A G G Y Y C T A D N S Y G 366
1156 GAGACAGAGCTGGAGCTCCCTGCCATCAGACAGAGCCATGCAGGGGGATACTACTGTACAGCAGACAACAGCTACG
P V Q S M V L N V T V R E T P G N R D G L V A A G 391
1233 GCCCTGTCCAGAGCATGGTGTGAATGTCACTGTGAGAGAGACCCAGGCAACAGAGATGGCCTTGTGCGCGGGGA
A T G G L L L S A L L A V A L L E H C W R R R K S G 417
1310 GCCACTGGAGGGCTGCTCAGTGTCTTCTCTGGCTGTGGCCCTGCTGTTCACTGCTGGCGTCCGAGGAAGTCAGG
V G F L G D E T R L P P A P G P G E S S H S I C P A 443
1387 AGTTGTTTCTTGGGAGACGAAACAGGCTCCCTCCCGCTCCAGGCCAGGAGATCCTCCCATTCATCTGCCCTG
Q V E L Q S L Y V D V H P K K G D L V Y S E I Q T 468
1464 CCCAGTGGAGCTTCACTGCTGTATGTTGATGTACACCCCAAGGGAGATTTGGTATACTCTGAGATCCAGACT
T Q L G E E E E A N T S R T L L E D K D V S V V Y S 494
1541 ACTCAGCTGGGAGAAGAAGAGGAAGCTAATACCTCCAGGACACTTCTAGAGGATAAGGATGTCTCAGTTGTCTACT
E V K T Q H P D N S A G K I S S K D E E S * 515
1618 TGAGGTAAAGACACAACACCCAGATAACTCAGCTGGAAAGATCAGCTCTAAGGATGAAGAAAGTTAAGAGAATGAAA
1695 AGTTACGGGAACGTCCTACTCATGTGATTTCTCCCTTGTCCAAAGTCCCAGGCCAGTGCAGTCTTGGCGCACCTG
1772 GAATGATCAACTCATTCAGCTTTCTAATCTTCTCATGCATATGCATTCACTCCAGGAATACTCATTCTGCTACT
1849 CTGATGTTGGGATGGAATGGCCTCTGAAAGACTTCACTAAATGACCAGGATCCACAGTTAAGAGAAGACCTGTAG
1926 TATTTGCTGTGGGCTGACCTAATGCATTCCCTAGGCTCTGCTTTAGAGAAGGGGGATAAAGAGAGAGAAGGACTGT
2003 TATGAAAACAGAAGCACAATTTTGGTGAATTGGGATTTGCAGAGATGAAAAGACTGGGTGACCTGGATCTCTGC
2080 TTAATACATCTACAACCATTTGCTCACTGGAGACTCACTTGCATCAGTTTGTAACTGTGAGTGGCTGCACAGGCA
2157 CTGTGCAACAAATGAAAAGCCCTTCACTTCTGCCTGCACAGCTTCACTGTCAGGATTCAGTTGCAGATTAAGAA
2234 CCCATCTGGAATGGTTTACAGAGAGAGGAATTTAAAGAGGACATCAGAAGAGCTGGAGATGCAAGCTCTAGGCTGC
2311 GCTTCCAAAAGCAAATGATAATTATGTTAATGTCATTAGTGACAAAGATTGCAACATTAGAGAAAAGAGACACAAA
2388 TATAAAATTAATAAATAAGTACCAACTCTCCAAAATAAATTTGAACCTAAAATATTAGTATAAACTCATATAAA
2465 CTCTGCCTTTAAATAAAAAAAAAAAAAAAAAAAAAA

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FIGURE 6a

1 CGGTGCAGTGTCTGACTGTAAGATCAAGTCCAAACCTGTTTGGGAATTGAGGAACTTCTCTTTGATCTCAGCCCTTG
N L L W V I L L V L A P V S G V Q F A R T P R 22
81 GTGGTCCAGGTCTTCATGCTGCTGTGGGTGATATTACTGGTCTGGCTCCTGTCAGTGGACAGTTTGGCAAGGACACCCAG
P I I F L Q P P W T T V F Q G E R V T L T C K G F R F 49
161 GCCCATTATTTCTCCAGCTCCATGGACACAGTCTTCCAAGGAGAGAGAGTACCCTCACTTGCAAGGGGATTTCCGT
Y S P Q K T K W Y H R Y L G K E I L R E T P D N I L 75
241 TCTACTCACCACAGAAAACAAATGGTACCATCGGTACCTTGGGAAAGAAATACTAAGAGAAACCCAGACAATATCCTT
E V Q E S G E Y R C Q A Q G S P L S S P V H L D F S S 102
321 GAGGTTGAGGAATCTGGAGAGTACAGATGCCAGGCCAGGGCTCCCTCTCAGTAGCCCTGTGCACTTGGATTTTCTTC
A S L I L Q A P L S V F E G D S V V L R C R A K A E V 129
401 AGCTTCGCTGATCTGCAAGCTCCACTTCTGTGTTTGAAGGAGACTCTGTGGTCTGAGGTGCCGGGCAAAGCGGGAAG
T L N N T I Y K N D N L A F L N K R T D F H I P H 155
481 TAACACTGAATAATACTATTACAAGATGATAATGTCCTGGCATTCTTAATAAAAGAACTGACTTCCATATTCCTCAT
A C L K D N G A Y R C T G Y K E S C C P V S S N T V K 182
561 GCATGTCTCAAGGACAATGGTGCATATCGCTGTACTGGATATAAGGAAAGTTGTTGCCCTGTTTCTTCCAATACAGTCAA
I Q V Q E P F T R P V L R A S S F Q P I S G N P E V A 209
641 AATCCAAGTCCAAGGCCATTTACAGCTCCAGTGTCTGAGAGCCAGCTCCTTCCAGCCCATCAGCGGGAACCCAGTGACCC
T C E T Q L S L E R S D V P L R F R F F R D D Q T L 235
721 TGAGCTGTGAGACCCAGCTCTCTAGAGAGGTACAGATGCCGCTCCGCTCCGCTTCTTCCAGAGATGACGAGACCCCTG
G L G W S L S P N F Q I T A M W S K D S G F Y W C K A 262
801 GGATTAGGCTGGAGTCTCTCCCGAATTTCCAGATTACTGCCATGTGGAGTAAAGATTACGGGTTTACTGGTGTAAAGGC
A T M P H S V I S D S P R S W I Q V Q I P A S H P V 289
881 AGCAACAATGCCCTCAGCGCTCATATCTGACAGCCCGAGATCCTGGATACAGGTGAGATCCCTGCATCTCATCTCTGTC
T L S P E K A L N F E G T K V T L H C E T Q E D S L 315
961 TCACTCTCAGCCCTGAAAAGGCTCTGAATTTTGAAGGAACCAAGGTGACACTTCACTGTGAACCCAGGAAGATTCTCTG
R T L Y R F Y H E G V P L R H K S V R C E R G A S I S 342
1041 CGCACTTTGTACAGGTTTATCATGAGGGTGTCCCTGAGGCACAAGTCAGTCCGCTGTGAAGGGGAGCATCCATCAG
F S L T T E N S G N Y Y C T A D N G L G A K P S K A V 369
1121 CTCTCTGACTACAGAGAATTCAGGGAATCTGACAGCTGACAATGGCCTTGGCGCCAAGCCAGTAAGGCTG
S L S V T V P V S H P V L N L S S P E D L I F E G A 395
1201 TGAGCCTCTCAGTCACTGTCTCCCGTGTCTCATCTGTCTCAACCTCAGCTCTCTGAGGACCTGATTTTGAAGGGAGCC
K V T L H C E A Q R G S L P I L Y Q F H H E D A A L 422
1281 AAGGTGACACTTCACTGTGAAGCCAGAGGTTTCACTCCCATCTGTACCACTTTCATCATGAGGATGCTGCCCTGGA
R R S A N S A G G V A I S F S L T A E H S G N Y Y C 449
1361 CGGTAGTTCGGCCAATCTGTCAGGAGGAGTGGCCATCAGCTTCTCTGACTGCAGAGCATTGAGGGAATCTACTGCA
A D N G F G P Q R G S K A V S L S I T V P V S H P V 475
1441 CAGCTGACAATGGCTTTGGCCCCCAGCGCAGTAAGGCGGTGAGCCTCTCCATCACTGTCCCTGTGTCTATCCTGTCTC
T L S S A E A L T F E G A T V T L H C E V Q R G S P Q 502
1521 ACCCTCAGCTCTGCTGAGGCCCTGACTTTTGAAGGAGCCACTGTGACACTTCACTGTGAAGTCCAGAGAGGTTCCCCACA
I L Y Q F Y H E D M P L W S S S T P S V G R S F S 529
1601 AATCCTATACAGTTTATCATGAGGACATGCCCTGTGGAGCAGCTCAACACCTCTGTGGGAAGAGTGTCTTTCAGCT
S L T E G H S G N Y Y C T A D N G F G P Q R S E V V 555
1681 TCTCTGACTGAAGGACATTCAGGGAATTAATACTGACAGCTGACAAATGGCTTTGGTCCCGCAGGCAAGTGGTG
S L F V T V P V S R P I L T L R V P R A Q A V V G D L 582
1761 AGCCTTTTGTCACTGTTCAGTGTCTCGCCCCATCTTCACTTCCAGGGTTCAGGGCCAGGCTGTGGTGGGGGACCT
L E L H C E A P R G S P P I L Y W F Y H E D V T L G 569
1841 GCTGGAGCTTCACTGTGAGGCCCCGAGAGGCTCTCCCCAATCTGTACTGGTTTATCATGAGGATGTACCCTGGGGA
S S A P S G G E A S F N L S L T A E H S G N Y S C E 635
1921 GCAGCTCAGCCCCCTCTGGAGGAGAAGCTTCTTCAACCTCTCTGACTGCAGAACATTCTGGAACACTACTCATGTGAG
A N N G L V A Q H S D T I S L S V I V P V S R P I L 662
2001 GCCAACAATGGCCTAGTGGCCACAGTACACAATATCACTCAGTGTATAGTTCAGTATCTCGTCCCATCTCTAC
F R A P R A Q A V V G D L L E L H C E A L R G S S P 1689
2081 CTTCAAGGCTCCCAGGGCCAGGCTGTGGTGGGGACCTGCTGGAGCTTCACTGTGAGGCGCTGAGAGGCTCTCCCAA
L Y W F Y H E D V T L G K I S A P S G G G A S F N L 715
2161 TCCTGTACTGGTTTATCATGAAGATGTACCCCTGGGTAAGATCTCAGCCCCCTCTGGAGGAGGGGCTCTTCAACCTC
S L T T E H S G I Y S C E A D N G L E A Q R S E M V 742
2241 TCTCTGACTACAGAACATTCTGGAATCTACTCTGTGAGGCAGACAATGGTCTGGAGGCCAGCGCAGTGAGATGGTGAC
L K V A G E W A L P T S S T S E N * 759
2321 ACTGAAAGTTGACGGTGTGAGTGGGCCCCGCCACCAGCAGCACATCTGAGAACTGACTGTGCCTGTTCTCCCTGCAGCTGA
2401 AAATGGAGCCACAGAGCTCTCAGGGCTGTTTCTGTGTGGCATCCCAGCACACTTCTGCTGCAGAACCTCCCTGTG
2481 AAAGTCTCGGATCTTTCTGGTATGGTTCCAGGAATCTGATGTTTCCAGCAGTCTTCTTGAAGATGATCAAGCACCTC
2561 ACTAAAAATGCAATAAGACTTTTGTAGAACATAAACTATATCTGAAGTGAATATTACATGAAAATGAAACCAAGA
2641 ATTCTGACATATGTTTCTGCGGTAGAAAGGATTAAGCTGTTTCTGTCCGATTCTTCTCATTGACTTCTAAGAA
2721 GCCTCTACTCTGTAGTCTCTTTCATTACTGGGGATGTAATGTTTCTTACATTTCCACATTAATAATCTATGTTAACGA
AAAAA

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FIGURE 6b

	CGGTGCAGTGTCTCGACTGTAAGATCAAGTCCAAACCTGTTTGGAAATGAGGAACCTCTCTTTGATCTCAGCCCTTG	
21	MLLWVILVLA PVS GQ FARTPR	22
	GTTGTCAGGTCCTTCAGTCTGCTGTGGGTGATATTACTGGTCTGGCTCTCTGTCAGTGGACAGTTTTCGAAGGACACCCAG	
161	PIIFLQPPMTTVFQGERVLTLCRGFRF	49
	GCCCATTTATTTCTCCAGCCTCCATGGACACAGTCTTCAAGGAGAGAGATGACCCCTCACTTGAAGGGATTTCGCT	
241	YSPQKTKWYHRYLKGKILRET P D N I L	75
	CTTACTCACCACGAAACAAATGGTACCATCGTACCTTGGGAAAGAAATACTAAGAGAAACCCGACACAAATATCTT	
321	EVQESGEYRCQAAGSPLSSPVHLD FSS	102
	GAGGTTCCAGGAATCTGAGAGTACAGATGCCAGGCCGCTCCCTCTCAGTAGCCCTGTGCATCTGGATTCTTCTTC	
401	ASLILQLAPLSVFEGD S V V L R C R A K A E V	129
	AGCTTCGCTGATCTGCAAGCTCCACTTCTGTGTTGAAGGAGACTCTGTGTTCTGAGGTCCGGGCAAGCGCGGAAG	
481	T L N N T I Y K N D N V L A F L N K R T D F H I P H	155
	TAACACTGAATAACTATTACAAGAATGATAATGCTTGGCATCTCTTAATAAAGAGACTGACTTCCATATTCTCAT	
561	ACLKNDNGAYRCTGTGYKESCCPVSSNTVK	182
	GCAITGCTCAAGGACAAATGTCATGCTGTCATGATATAAGGAAAGTTGTTGCCCTGTTTCTTCCAATTACAGTCAA	
641	I Q V Q E P F T R P V L R A S S F Q P I S G N P V T L	209
	AATCCAAGTCCAAGAGCCATTTACACGTCAGTGTGAGAGCCAGCTCTCTCCAGCCCATCAGCGGGAACCCAGTGAACCC	
721	T C E T Q L S L E R S D V P L R F R F R R D D Q T L	235
	TGACCTGTGAGACCCAGCTCTCTAGAGAGGTGAGATGTCCCGCTCCGGTCTCTTCCAGATGACCCAGCCCTG	
801	G L T W S L S P N F Q I T A H W S K D S G F Y W C K A	262
	GGATTAGGCTGGAGTCTTCCCGAATTTCAGATTACTGCCATGTGGAGTAAAGATTACAGGTTCTACTGGTGTAAAGC	
881	A T M P H S V I S D S P R S W I Q V Q I P A S H P V L	289
	AGCAACAATGCCCTCAGAGCTCATATCTGACAGCCCGAGATCTTGATACAGGTGCGAGATCCCTGCATCTCATCTGTCT	
961	T L S P E K A L N F E G T K V T L H C E T Q E D S L	315
	TCACTCTCAGCCCTGAAAGGCTGTGAATTTTGAAGGAAACCAAGGTGACACTTCACTGTGAAACCCAGGAAGATTCTGT	
1041	R T L Y R F Y H E G V P L R H K S V R C E R G G A S I S	342
	CGCACTTTGTACAGGTTTATCATGAGGGGTGCCCTTGAGGCAAGTCAGTCCGCTGTGAAGGGAGCATCCATCAG	
1121	F S L T E N S G N Y Y C T A D N G L G A K P S K A V	369
	CTTCTCACTGACTACAGGAATTCAGGGAACACTACTGACAGCTGACAATGGCTTGGCGCCCAAGCCAGTAAGGCTG	
1201	T L S V T V P V S H P V L N L S P E D L I F E G A	395
	TGAGCCTCTCAGTCACTGTCCCGTGTCTATCTGCTCACTCACTCAGCTCTCTGAGGACCTGATTTTCTGGGGAGCC	
1281	K V T L H C E A Q R G S T G P I L Y Q F H H E D A A L E	422
	AAGGTGACACTTCACTGTGAAGCCAGAGAGGTTCACTCCCCATCTGTACCAAGTTTATCATAGGATGCTGCCCTGGA	
1361	R R S A N S A G G V A I S F S L T A E H S G N Y Y C T	449
	GGTAGGTGGCCCAACTCTGAGGAGGAGTGGCCATCAGCTTCTCTGACTGACAGCAATTGAGGGAACCTACTACTGCA	
1441	A D N G F G P Q R S K A G T S L S I T V P V S H P V L	475
	CAGCTGACAATGGCTTGGCGCCCGAGCGCAGTAAGCGGTGAGCCTCTCATCTGCTGCTGTCTCATCTCTGCTCT	
1521	T L S S A E A L T F E G A T V T L H C E V Q R G S P Q	502
	ACCTCAGCTCTGCTGAGGCTGACTTTTGAAGAGCCGCTGTGACACTTCACTGTGAAGTCCAGAGAGGTTCCCCACA	
1601	I L Y Q F Y H E D M P L S S S T P S V G R V S F S F	529
	AATCCTATACCAAGTTTATCATGAGGACATGCCCTTGAGGAGCTCAACACCCCTCTGTGGGAAGAGTGTCTCTCAGCT	
1681	S L T E G H S G N Y Y C T A D N G F G P Q R S E V V	555
	CTCTCTGACTGAAGGACATCAGGGAATTAATCTGCAAGCTGCAATGGCTTTGGTCCCAGCGCAGTGAAGTGGT	
1761	S L F V T G K C W V L A S H P P L A E F S L T H S F C	582
	AGCCTTTTGTCACTGGTAAGTGTGGTCTTGGCAGTACCCACCCCTGAGTCTCTCTCAACCCATCTCTTA	
1841	N L F A L S S F L P - stop	592
	AAATCTGTTGACATGTCAGTTTCTCCCTTAATCAACTTAATCCCTTCTTGCTCTCTCTCAACTAAGTCTGGG	
1921	3TTTCCGTACTCATAAGTCTGGCTGAGCGAGACCTTAAACAGCTCAGTAGATTCCCGAGCTTTTACCAATGAATT	
2001	TATTATTGTATTCTCTCATCTCTCTGTATGTCTTCAACAGTACGCCCAATTTTCTGATGACCGGAGCTGTCTTACT	
2081	TCTCTACTGACATTTACATATTAAGTCTGACAGACAGTCTATAGATAAATTTGGTCAAGCACTTAAATTTCTTCCA	
2161	AGGATTTTCCAATTTATGTAGATTGGGAGAAAGCTGCTGGTGAACAAGAGGAAATGGCTCCTTAGGAACCACTCC	
2241	CTCAAACTCTGGAGTTTATGATCCCTGTGTTTCTAACTCTGATAAATCAGTATCAITTTATGTTATTTTAAAAAA	
2321	ACTATTGTGTAAGTATGACATATCAAGAAAGCTGTGCAATTTGTATGTGACCAATTTGTTGTTTCTGATGTTAAAA	
2401	GTGCTCTCTGTTTACTTGAATCTTTGTATTAGAAACTGGGGGAAAGTTTACTTTCTTTCAGAGAGCCCAATGGTA	
2481	TGATAGAAAAATCTTGAGCCTGATGTGTCAGACATGCCCTCATGATACTTGTGAGTAAAGAGGTTATTTTAAAAATG	
2561	GAATGTTCTGACAGTACTCTAAAGTTCAGAGCGCAAACTTACTAGGAAGCTTGTAGACTCACTCATCTTCTGATCCCAT	
2641	TATCTTTTATCCAGTTTCAACTTCTTCTCATATTCAGCAGCATCTTAAGCTCTTTATTTCTGTTTCTTCTGATGTA	
2721	CCCTTAATGCCAGTAGAATGTAAAGCTCATGAGAACAGAACTGCATCCATCTTGCTCTTCAACATCCCTGTGCCCTACT	
2801	CAGTGTTTGGCACAGATAGGCTCTCAGTCAACATTTGAATTTAGTGGACAGATGATGACAGAGTATGAAAGAGGGGA	
2881	TTTAAAAAATCATCTAGCAAGGCCAAGGAAAAAACAAGCAATTTTATGAAATGAATACCAATTTTGAAGAGGTA	
2961	AGAATAGATTGGATATTTTGAAAATCAATTAATGATGAAGAACCAATTTGAGAAACAAATACAGAAATGCAAGTAGAA	
3041	AGATACAGAAATTAAGGCAAAATTTAATATGGAATGAAATCAGACAAATGGATTGTTCTGTATCCAGTTTATGGTAAATTA	
3121	AATGCAAGACCTTCAGAAATGCAACCGAAGAGTAAATGAAACTCAAAATGATAGTAATGTTGGGAAGTAAAGAAA	
3201	ACTTGAATATGTAGATCAGAACATATATGTTGATGACGTTTATGACTTTGAGGTTAAATATATATATGTGCTCATGAT	
3281	TGTGGGAAAAAAGCAGCTGCTCAGAAAGAAACAACTCAAGTTAGTCTTGAGACTTGGAGTGCATCAGTACCAAGAG	
3361	AGAGGAGGGCCAGCTTGACCTCGGAGGGAGAAATTAACCGAAAAATTTATCAATTTAAAAAGACATTGTCAAAAA	
3441	TACAGGATTTCAGGAATCAGAAATGCAATAGCTTCTGAAAAAACCACTTAAT	

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FIGURE 6c-1

1 CGGTGCAGTGCTCTGACTGTAGATCAAGTCCAAACCTGTTTGGAAATTGAGGAACTCTCTTTGATCTCAGCCCTTG
 H L L W V I L L V L A P V S G V Q F A R T P R 22
 21 GTGGTCCAGGTCTTCATGCTGCTGTGGGTGATATTACTGGTCTGGCTCTGTCAGTGGACAGTTTSCAAGGACACCCAG
 P I I F L Q P P W T T V F Q G E R V T L T C K G F R F 49
 161 GCCCATTTATTTCTCCAGCCTCCATGGACACAGTCTTCCAAGGAGAGAGAGTGACCTCCTCTGCAAGGGGATTTCGGCT
 Y S P Q K T K W Y H R Y L G K E I L R E T P D N I L 75
 241 TCTACTCACCACAGAAAACAAATGGTACCATCGGTACCTTGGGAAAGAAATACTAAGAGAAACCCACACATATCCTT
 E V Q E S G E Y R C Q A O G S P L S S P V H L D F S S 102
 321 GAGGTTGAGGAATCTGGAGAGTACAGATGCCAGGCCAGGGCTCCCTCTCAGTAGCCCTGTGCATTTGGATTTCCTC
 A S L I L Q A A P L S V F E G D S V V L R C R A K A E V 129
 401 AGCTTCGGTGTATCTGCAAGCTCCACTTTCGTGTTGAAGGAGACTCTGTGGTTCTGAGGTGCCGGCAAAGCCGGAAG
 T L N N T I Y K N D N V L A F L N K R T D F H I P H 155
 481 TAACACTGAATAATACTATTTACAAGAATGATAATGTCTGGCATTCTTAATAAAGAACTGACTTCCATATTCCTCAT
 A C L K D N G A Y R C T G Y K E S C C P V S S N T V K 182
 561 GCACTGTCAAGGACAATGGTGCATATCGCTGACTGTGATATAAGGAAAGTTGTTGCCCTGTCTTCTCAATACAGTCAA
 I Q V Q E P F T R P V L R A S S F Q P I S G N P V T L 209
 641 AATCAAGTCCAAGAGCCATTACAGCTGCTGAGAGCCAGCTCTCTCCAGCCCATCAGCCGGAACCCAGTGACCC
 T C E T Q L S L E R S D V P L R F R F F R D D Q T L 235
 721 TGACCTGTGAGACCCAGCTCTCTCTAGAGAGGTGAGATGCTCCGCTCCGGTCTCTCTCAGAGATGACCAACCCCTG
 G L G W S L S P N F Q I T A M W S K D S G F Y W C K A 262
 801 GGATTAGGCTGGAGTCTCTCCCGAATTTCAGATTAAGTGGATTAAGATTGAGGGTCTACTGTTGTAAGGC
 A T M P H S V I S D S P R S W I Q V Q I P A S H P V L 289
 981 AGCAACAATGCTCAGAGCTCATATCTGACAGCCGAGATCTGGATACAGGTGCAGATCCCTGCATCTCCTCTGCC
 T L S P E K A L N F E G T K V T L H C E T Q E D S L 315
 961 TCACTCTCAGCCCTGAAAAGGCTCTGAATTTGAGGGGAACCAAGGTGACACTTCACTGTGAAACCCAGGAAGATTCTCTG
 R T L Y R F Y H E G V P L R H K S V R C E R G A S I S 342
 1041 CGCAGTTTGTACAGGTTTATCATGAGGGTGTCCCGCTGAGGCACAAGTCAGTCCGCTGTGAAAGGGGAGCATCCATCAG
 F S L T T E N S G N Y Y C T A D N G L G A K P S K A V 369
 1121 CTTCTCACTGACTACAGAGAATTGAGGAACTACTACTGCACAGCTGACAATGGCCTTGGCGCAAAGCCAGTAAGGCTG
 S L S V T V P V S H P V L N L S S P E D L I F E G A 395
 1201 TGAGCCTCTCAGTCTGCTCCCGTGTCTCTCAACCTCAGCTCTCTGAGGAGCTGATTTTGGAGGAGCC
 K V T L H C E A Q R G S L P I L Y Q F H H E D A A L E 422
 1281 AAGGTGACACTTCACTGTGAAGCCAGAGAGGTCTACTCCCATCTGTACCACTTTCATCATGAGGATGCTGCCCTGGA
 R R S A N S A G G V A I S F S L T A E H S G N Y Y C T 449
 1361 GCGTAGGTCGGGCAACTCTGCAGGAGGAGTGGCCATCAGCTTCTCTGACTGCAGAGCATTCAGGGAAGTACTACTGCA
 A D N G P G P Q R S K A V S L S I T V P V S H P V L 475
 1441 CAGCTGACAATGGCTTTGGCCCCAGCGCAGTAAGCGGTGAGCCTCTCCATCACTGTCCCTGTGTCTCATCTGTCTCT
 T L S S A E A L T F E G A T V T L H C E V Q R G S P Q 502
 1521 ACCCTCAGCTCTGCTGAGGCCCTGACTTTTGAAGGAGCCACTGTGACACTTCACTGTGAAGTCCAGAGAGGTTCCTCCACA
 I L Y Q F Y H E D H P L W S S S T P S V G R V S F 529
 1601 AATCCTATACAGTTTATCATGAGGACATGCCCCCTGTGGAGCAGCTCAACACCTCTGTGGGAAGAGTGTCTCTCAGCT
 S L T E G H S G N Y Y C T A D N G F G P Q R S E M V T 555
 1681 TCTCTGACTGAAGGACATTGAGGAATTACTACTGCACAGCTGACAATGGCTTGGTCCCCAGCGCAGTGAAGTGGTG
 S L F F V T V P V S R P I L T L R V P R A Q A V V G D L 582
 1761 AGCCTTTTGTCACTGTTCAGTGTCTGCCCTCTCAGCTTCTCAGGCTTCCAGGGCCAGGCTGTGGTGGGGAGCT
 L E L H C E A P R G S P P I L Y M F Y H E D V T L G S 609
 1841 GCTGGAGCTTCACTGTGAGGCCCGGAGAGGCTCTCCCAATCTGTACTGGTTTATCATGAGGATGTCACTTGGGGA
 S S A P S G G E A S F H L S L T A E H S G N Y Y C E 635
 1921 GCAGCTCAGCCCCCTCTGGAGGAGAGCTTCTTCAACCTCTCTGACTGCAGAACATTCTGGAAGTACTCATGTGAG
 A N N G L V A Q H D T I S L S V I V P V S R P I L T 662
 2001 GCCAACAAATGGCTAGTGGCCAGCAGTGCACAAATATCACTAGTGTATAGTTCAGTATCTCGTCCCATCTCAC
 F R A P R A Q A V V G D L L E L H C E A L R G S S P I 689
 2081 CTTCAAGGCTCCAGGGCCAGGCTGTGGTGGGGGACCTGCTGGAGCTTCACTGTGAGGCCCTGAGAGGCTCTCCCCAA
 L Y W F Y H E D V T L G K I S A P S G G G A S F N L 715
 2161 TCCTGTACTGGTTTATCATGAAGATGTCACTCTGGGTAAAGATCTCAGCCCCCTCTGGAGGAGGGGCTCTTCAACCTC
 S L T T E H S G I Y S C E A D N G L E A Q R S E M V T 742
 2241 TCTCTGACTACAGAACATTCTGGAATCTACTCTGTGAGGCAGACAATGGTCTGGAGGCCAGCGCAGTGAAGTGGTGAC
 L K V A V P V S R P V L T L R A P G T H A A V V G D L L 769
 2321 ACTGAAAGTTGAGTTCCGGTGTCTCGCCCGGCTCTCAGCTCAGGGCTCCCGGACCCATGCTGCGGTGGGGGACCTGC
 E L H C E A L R G S P L I L Y R F F H E D V T L G N 795
 2401 TGGAGCTTCACTGTGAGGCCCTGAGAGGCTCTCCCTGATCTGTACCGGTTTTCATGAGGATGTCACTTGGGAAAT
 R S S P S G G A S L N L S L T A E H S G N Y S E A D 822
 2481 AGGTGCTCCCCCTCTGGAGGAGCGTCTTAACTCTCTGACTGCAGAGCACTTGGAACTACTCTGTGAGGCGGA
 N G L G A Q R S E T V T L Y I T G L T A N R S G P F A 849
 2561 CAATGGCTCGGGGCCAGCGCAGTGAAGTGAACATTTATATCAGGGGCTGACCGGGAACAGAGTGGCCCTTTTG
 T G V A G G G L S L A G A L I Y C W I S R 875
 2641 CCACAGGAGTCCCGGGGCTCTCAGCATAGCAGGCTTCTGCGGGGGCACTGCTCTACTGCTGGCTCTCGAGA
 K A G R K P A S D P A R S S P S D S Q E P T Y H N V 902
 2721 AAAGCAGGAGAAAGCTTCCCTCTGACCCCGCAGGAGCCCTTCACTCGGAGTCCCAAGAGCCCACTATCAATGT
 P A W E E L Q P V Y T N A N P R G E N V V Y S E V R I 929
 2801 ACCAGCTTGGGAAGAGCTGCAACCACTGTACACTAATGCAATCTAGAGGAGAAAATGGTTTACTCAGAGTACGGA
 I Q E K K K H A V A S D P R H L R N K G S P I Y S 955
 2881 TCATCCAAGAGAAAAGAAACATGCAAGTGGCTCTGACCCAGGCACTTCAGGAACAAGGTTCCCTATCATCTACTCT

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FIGURE 6c-2

E V K V A S T P V S G S L F L A S S A P H R * stop 977

2961 GAAGTTAAGGTGGCGTCAACCCCGGTTTCGGGATCCCTGTTCTTGGCTTCCTCAGCTCCTCACAGATGAGTCCACACGTC
3041 TCTCCAACTGCTGTTTCAGCCTCTGCACCCCAAAGTTCCCTTGGGSGAGAAGCAGCATTGAAGTGGGAAGATTTAGGCT
3121 GCCCCAGACCATACTACTGGCCTTGTTCACATGTCCTCATTCTCAGTCTGACCAGAATGCAGGGCCCTGCTGGACTG
3201 TCACCTGTTTCCAGTTAAAGCCCTGACTGGCAGGTTTTTAATCCAGTGGCAAGGTGCTCCCACTCCAGGGCCAGCAC
3281 ATCTCTGGATTCTTGTAGTGGGCTTCAGCTGTGGTTGCTGTTCTGAGTACTGCTCTCATCACACCCCAAGAGGGGTC
3361 TTACCACACAAAGGCAGAGTGGGCTTCAGGAGATGCCGGGCTGGCCTAACAGCTCAGGTGCTCTAACTCCGACACAG
3441 AGTTCTGCTTGGGTGGATGCATTTCTCAATTGTTCATCAGCCTGGTGGGGCTACTGCACTGCTGCCAAATGGGACAG
3521 CACACAGCCTGTGCACATGGGACATGTGATGGGTCTCCCAAGGGGGCTGCATTTCACTCTCCACCTGTCTCAAAT
3601 CTAAGGTCCGCACTTGACACCAAGGTAACCTCTCTCTGCTCATGTGTCTAGTGTCTACCTGCCCAAGTAAGTGGCTTTCA
3681 TACACCAAGTCCCGAAGTTCTTCCATCCTAACAGAAGTAACCCAGCAAGTCAAGGCCAGGAGGACCAGGGGTGCAGACA
3761 GAACACATACTGGAACACAGGAGGTGCTCAATTACTATTGACTGACTGACTGAATGAATGAATGAATGAGGAAGAAAAC
3841 TGTGGGTAATCAAACCTGGCATAAAATCCAGTGCACCTCCCTAGGAAATCCGGGAGGTATTCTGGCTTCTTAAGAAACAACG
3921 GAAGAGAAGGAGCTTGGATGAAGAACTGTTTCCAGCAAGAAGAGGGCTTCTTCACTTTTATGTGCTTGTGGATCACT
4001 GAGGATCTGTGAAATACAGATACTGATTCAAGTGGGTCTGTGTAGAGCCTGAGACTGCCATTCTAACATGTTCCAGGGG
4081 ATGCTGATGCTGTGGCCCTGGGACTGCACCTGCATGTCATGTAAGCCCTATAGGTCTCAGCAGAGGCCCATGGAGAGGA
4161 ATGTGTGGCTCTGGCTGCCAGGGCCCACTCGGTTCCACCGGATCGTGTGCTCTCCCTGGCCAGCCTTTGGCCACAGCAC
4241 CACCAGCTGCTGTGTGCTGAGAGAGGTTCTTCTGTGACATGTTGGCTTTCATCAGCCACCCTGGGAAGCGGAAAGTAGC
4321 TGCCACTATCTTTGTTTCCCACTCAGGCTCAGACTTTCCCATGAAAAGGGTGAATGTATATAAAGCTGAGCCCTCTCC
4401 ATTCAGAGTTGTTCTCCATCTCTGAGCAATGGGATGTTCTGTTCCGCTTTTATGATATCCATCACATCTTATCTTGATC
4481 TTTGCTCCCACTGGATTGTACAGTGTGACTTTTAAGCCCCACGGCCCTGAAAATAAAATCCTTCCAGGGCATTTGGAAGC
4561 TCACTCCACCTGAACCATGGCTTTTCATGCTTCCAAGTGTGAGGCTTGGCCAGATAGACAGGGCTGACTCTGTGCCCC
4641 CAACCTTTCAAGGAGGAAACACAGACCTGAGACAGGAGCCTGTATGCAGCCAGTGCAGCCTTGAGAGGACAAGGCTG
4721 GAGGCAATTTGTCTACTACAGATATGCAACTAAATAGACGTGGAGCAAGAGAAATGCATTCCACCGAGGCGCTTTT
4801 TTAGGCCTAGTTGAAAGTCAAGAAGGACAGCAGCAAGCATAGGCTCAGGATTAAAGAAAAAATCTGCTCACAGTCTGTT
4881 CTGGAGGTCACATCACCACAAAGCTCACGCCCTATGCAAGTTCTGAGAAGGTGGAGGCCAGGCTCAAAGAGGAAAT
4961 TAGAATTTCTCATTTGGGAGAGTAAGGTACCCCATCCAGAAATGATAACTGCACAGTGGCAGAACAACTCCACCTAAT
5041 GTGGGTGGACCCCATCCAGTCTGTTGAAGGCTGAATGTAAACAAAAGGGCTTATTCTTCTCAAGTAAGGGGAACTCCT
5121 GCTTTGGGCTGGGACATAAGTTTTCTGCTTTCAGACGCAAACTGAAAAATGGCTCTTCTTGGGTCTTGAGCTTGCTGGC
5201 ATATGGACTGAAAGAACTATGCTATTGGATCTCCTGGATCTCCAGCTTGCTGACTGCAGATCTTGAGATATGTCAGCCT
5281 CTACAGTCACAAGAGCTAATTCATTAATAAACCAATCTTC

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FIGURE 8A

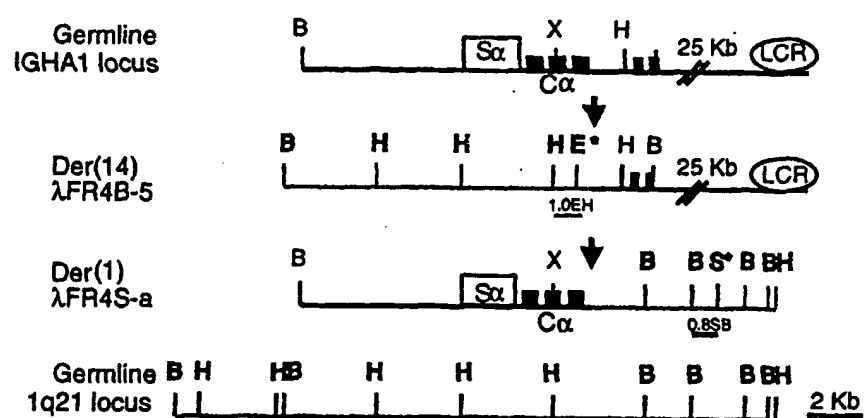
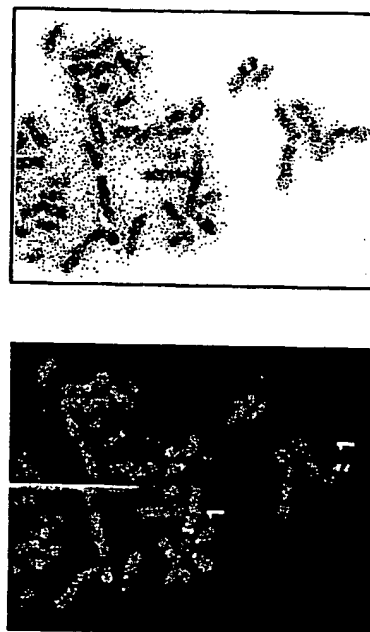


FIGURE 8

FIG. 8B

Chr 14	TCCCACTGACGCAATGCAGGAGGGGACCTCCCTTAAACCACTGCTCTGTACGGGGCACCTGGGCACAGGTGCACACTCACA
Der (14)	GGCCTGACAGCAACTTTTCTCTACTAGTTCATCTTAA-CACTGCTCTGTACGGGGCACCTGGGCACAGGTGCACACTCACA
Chr 1	GGCCTGACAGCAACTTTTCTCTACTAGTTCATCTTAACTTTATCCTGTTAACTGGCGAGACAACCTGTCTTAAGTAACTGAAGGGAAA
Chr 1	GGCCTGACAGCAACTTTTCTCTACTAGTTCATCTTAACTTTATCCTGTTAACTGGCGAGACAACCTGTCTTAAGTAACTGAAGGGAAA
Der (1)	TCCCACTGACGCAACTTTTCTCTACTAGTTCATCTTAACTTTATCCTGTTAACTGGCGAGACAACCTGTCTTAAGTAACTGAAGGGAAA
Chr 14	GGCCTGACAGCAACTTTTCTCTACTAGTTCATCTTAACTTTATCCTGTTAACTGGCGAGACAACCTGTCTTAAGTAACTGAAGGGAAA

8c



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FIGURE 9

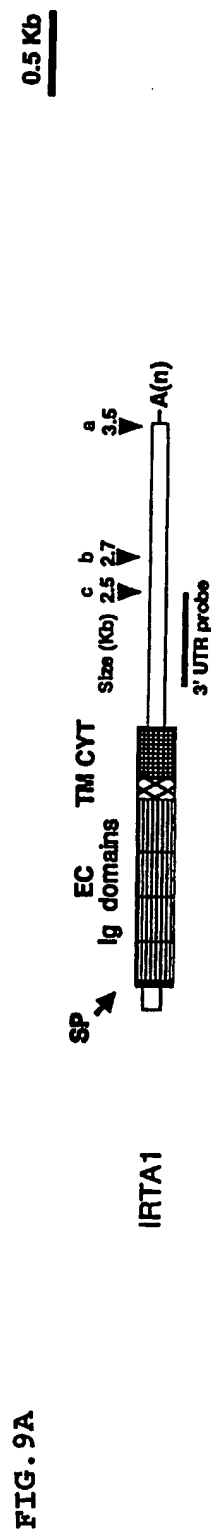
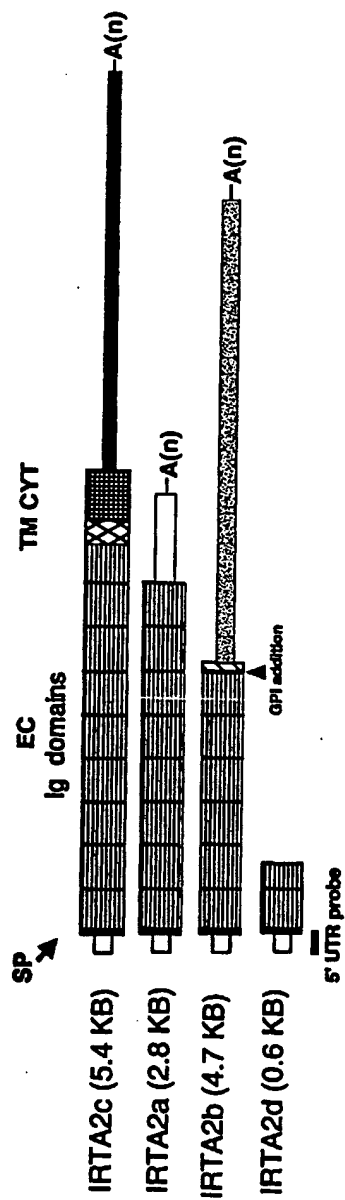


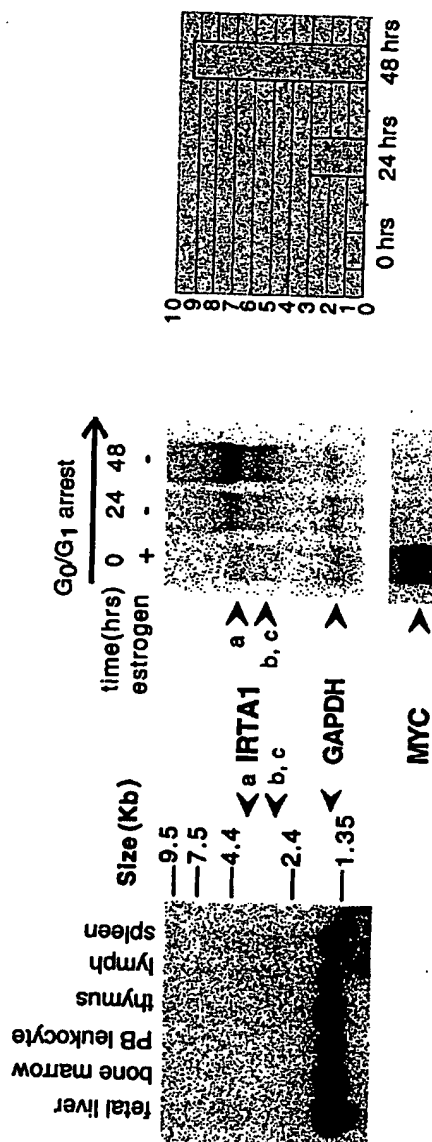
FIG. 9B



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FIGURE 11A

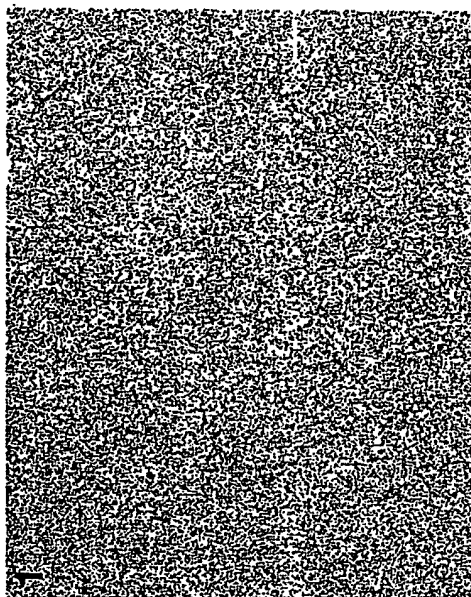
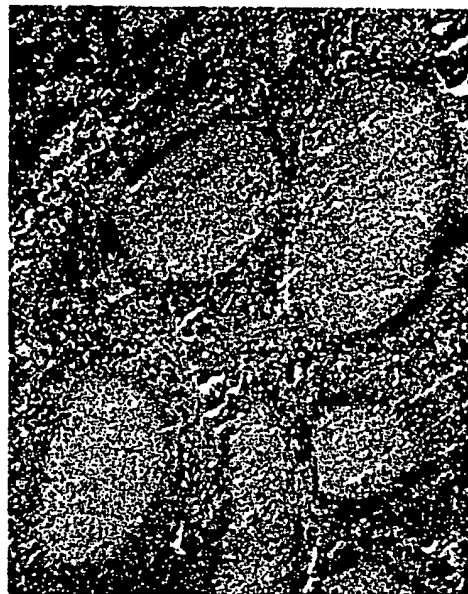
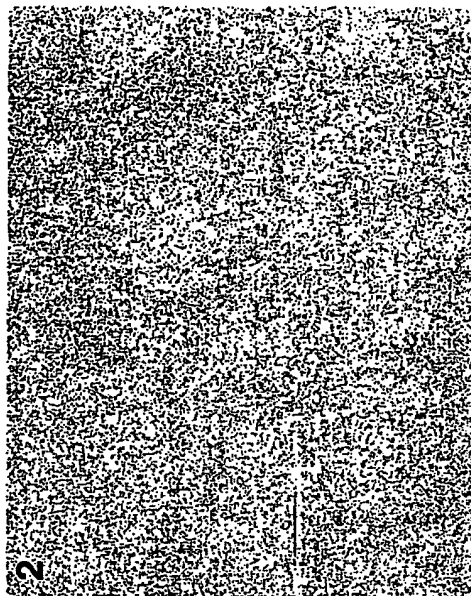
11A



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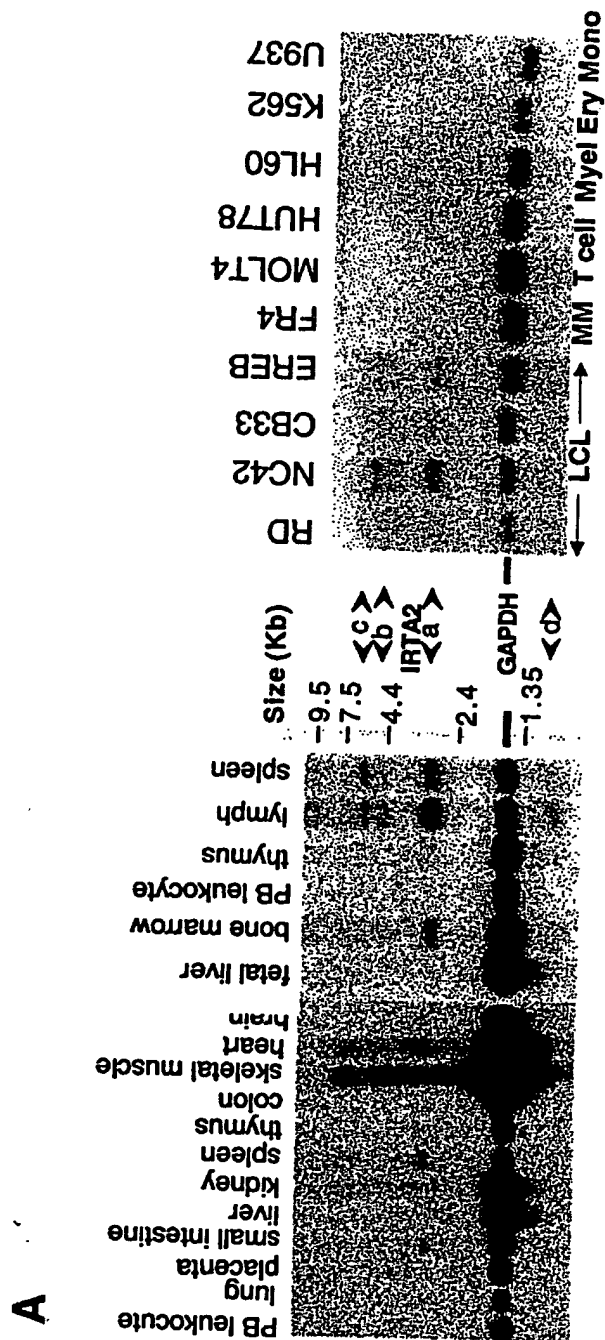
FIGURE 11B1-B4

11B1-4



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FIGURE 12A



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FIGURE 12B1-B4

B

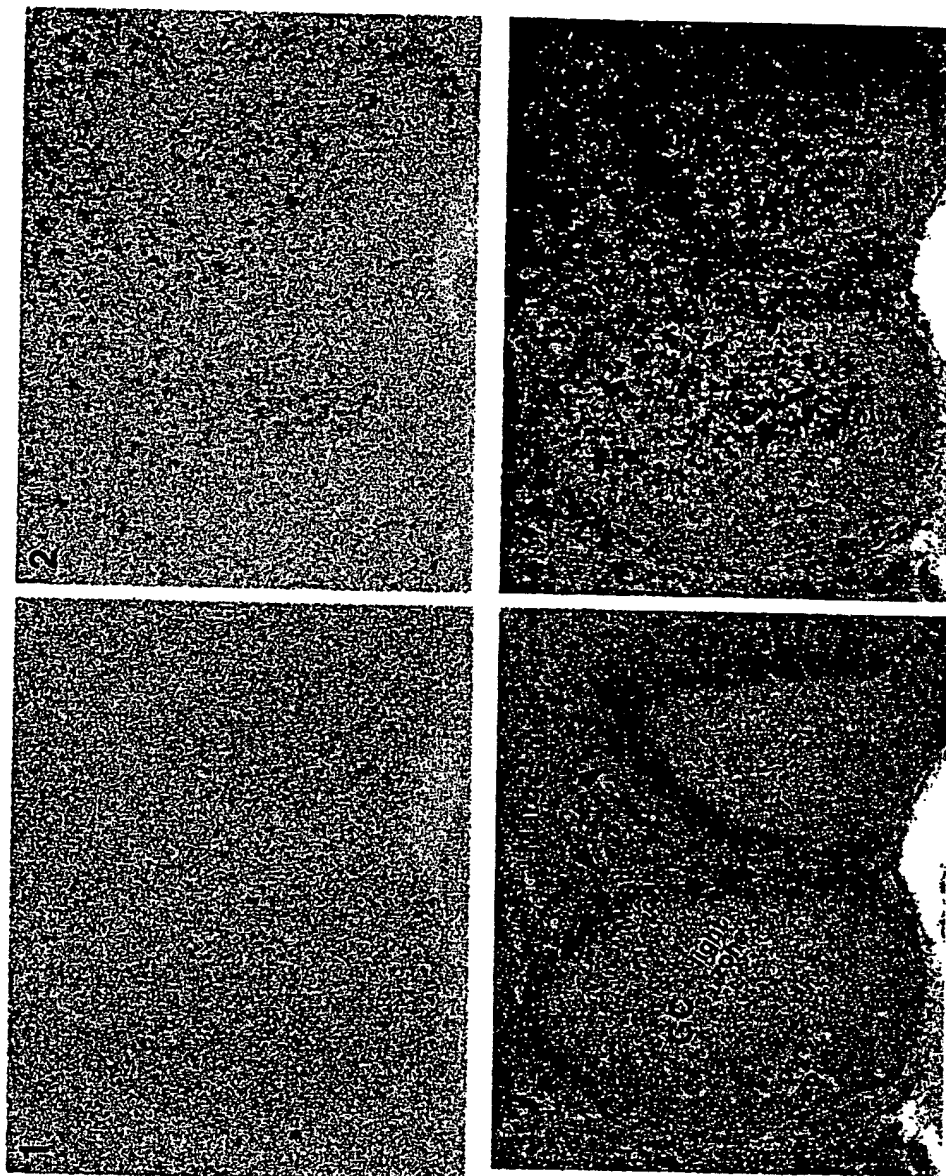


FIGURE 15

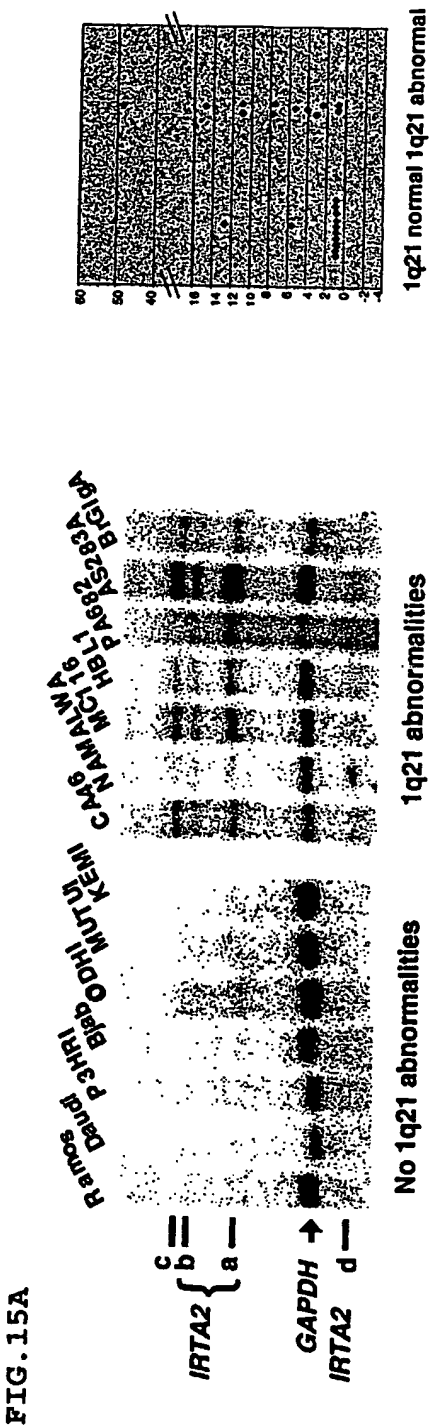
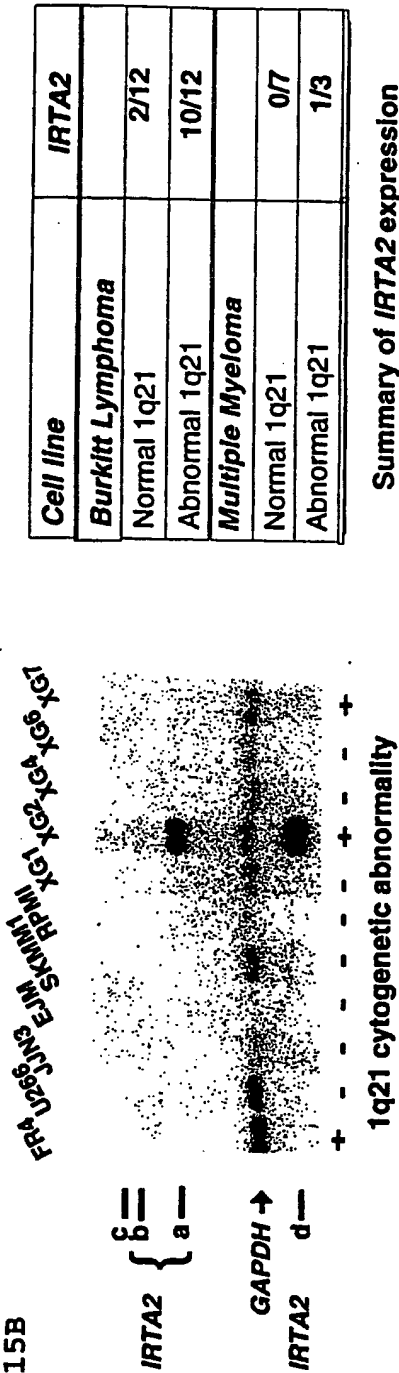


FIG. 15B

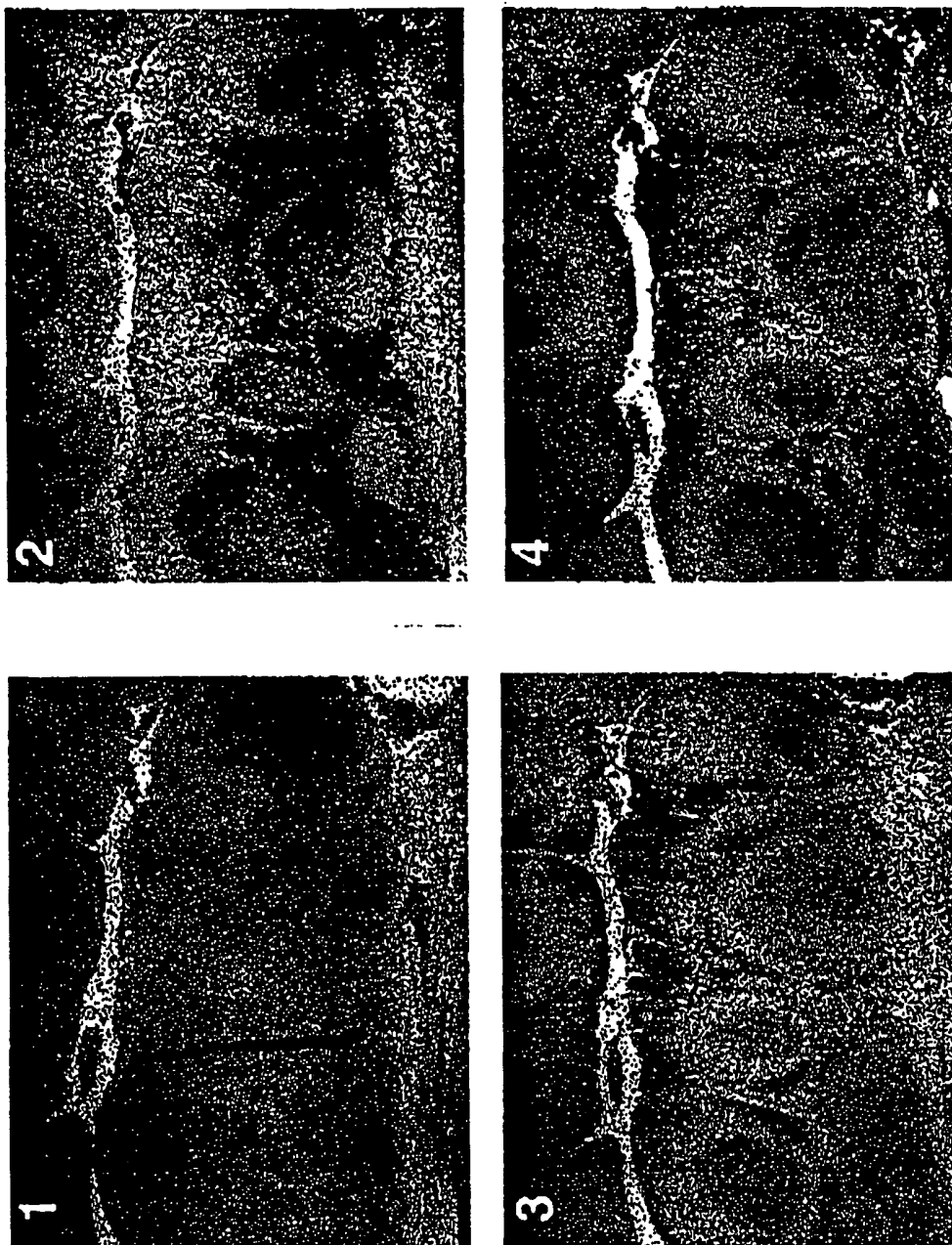


Cell line	IRTA2
Burkitt Lymphoma	
Normal 1q21	2/12
Abnormal 1q21	10/12
Multiple Myeloma	
Normal 1q21	0/7
Abnormal 1q21	1/3

Summary of IRTA2 expression

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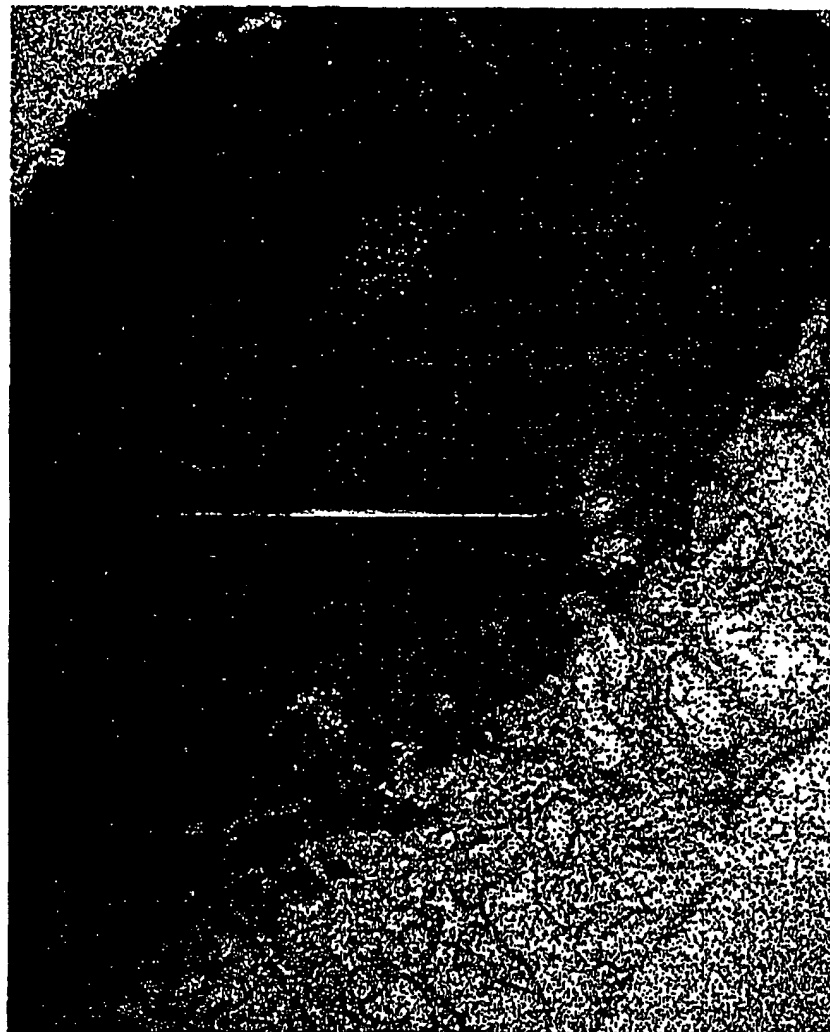
FIGURE 16-1-1~16-4
IRTA1 expression in normal lymphoid tissue



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FIGURE 17

IRTA1 expression in a stomach Mucosa-Associated-Lymphoid Tissue B cell lymphoma



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FIGURE 18A

1 CTCAATCAGCTTTATGCAGAGAAGAAGCTTACTGAGCTCACTGCTGGTGTGGTGTAGGCAAGTGTCTGCTTTGGCAA
M L L W A S 6
78 TCTGGGCTGACCTGGCTTGTCTCCTCAAACTCCTTCTCAACCTGGAGCAGGCTTCCATGCTGCTGTGGGCGTCC
L L A F A P V C G Q S A A A H K P V I S V H P P W T 32
155 TTGCTGGCCTTTGCTCCAGTCTGTGGACAATCTGCAGCTGCACACAAACCTGTGATTTCCGTCCATCCTCATGGAC
T F F K G E R V T L T C N G F Q F Y A T E K T T W Y 58
232 CACATTCTTCAAAGGAGAGAGTCTGACTTGCAATGGATTTCAGTTCTATGCAACAGAGAAAAACATCGT
H R H Y W G E K L T L T P G N T L E V R E S G L Y 83
309 ATCATCGGCACTACTGGGAGAAAAGTTGACCTGACCCAGGAAACACCTCGAGGTTCCGGGAATCTGGACTGTAC
R C Q A R G S P R S N P V R L L F S S D S L I L Q A 109
386 AGATGCCAGGCCCGGGGCTCCCCACGAAGTAACCTGTGCGCTTGTCTTTTCTTCAGACTCCTTAATCCTGCAGGC
P Y S V F E G D T L V L R C H R R R R K E K L T A V K 135
463 ACCATATTCTGTGTTTGAAGGTGACACATTGGTTCTGAGATGCCACAGAAGAAGAAAGAGAAATTGACTGCTGTGA
Y T W N G S I S N K S W D L L I P Q A S S N 160
540 AATATACTTGGAAATGGAACATTCTTTCCATTCTTAATAAAGCTGGGATCTTCTATCCCAAGCAAGCAATTCAAAT
N N G N Y R C I G Y G D E N D V F R S N F K I I K I 186
617 AACAAATGGCAATTATCGATGCATTGGATATGGAGATGAGAATGATGATTTAGATCAAATTTCAAATTAATTAAT
Q E L F P H P E L K A T D S Q P T E G N S V C 212
694 TCAAGAACTATTCCACATCCAGAGCTGAAAGCTACAGACTCTCAGCCTACAGAGGGGAATCTGTAAATCTGACT
E T Q L P P E R S D T P L H P N F F R D G E V I L 237
771 GTGAACACAGCTTCTCCAGAGCGGTGAGACACCCCACTTCACTTCAACTTCTTCAGAGATGGCAGGTCATCCTG
S D W S T Y P E L Q L P T V W R E N S G S Y W C G A 263
848 TCAGACTGGAGCAGTACCCGGAATCCAGCTCCCAACCGCTGGAGAGAAAACCTCAGGATCCTATTGGTGTGGTGC
E T V R G N I H K H S P S L Q I H V Q R I P V S G V 289
925 TGAACAGTGAAGGGTAAACATCCACAAGCAGTCCCTCGCTACAGATCCATGTGCAGCGGATCCCTGTGTGGGG
L L E T Q P S G G Q A V E G E M L V L V C S V A E 314
1002 TGCTCTGGAGACCCAGCCCTCAGGGGGCCAGGCTGTTGAAGGGGAGATGCTGGTCTTGTCTGCTCCGTGGCTGAA
G T G D T T F S W H R E D M Q E S L G R K T Q R S L 340
1079 GGCACAGGGGATACCACTTCTCTGGCACCAGAGAGGACATGCAGGAGAGTCTGGGAGGAGAACTCAGCGTTCCTC
R A E L E L P A I R Q S H A G G Y Y C T A D N S Y G 366
1156 GAGAGCAGAGCTGGAGCTCCCTGCCATCAGACAGAGCCATGCAGGGGATACTACTGTACAGCAGACAACAGCTACG
P V Q S M V L V R E T P G N R D G L V A A G 391
1233 GCCCTGTCCAGAGCATGGTGTGAATGTCACTGTGAGAGAGACCCAGGCAACAGAGATGGCCTTGTGCGCCGCGGA
A T G G L L S A L L L A V A L L F H C W R R R K S G 417
1310 GCCACTGGAGGGCTGCTCAGTGTCTTCTCTGGCTGTGGCCCTGCTGTTTCACTGTGCGCTCGGAGGAAGTCAGG
V G F L G D E T R L P P A P G P G E S S H S I C P A 443
1387 AGTGTGTTTCTTGGAGACGAAACAGGCTCCCTCCGCTCCAGGCCAGGAGAGTCTCCCATTCATCTGCGCTG
Q V E L Q S L Y V D V H P K K G D L V Y S E I Q T 468
1464 CCCAGGTGGAGCTTCACTGCTGTATGTGTATGTACACCCCAAAAGGAGATTGGTATACTCTGAGATCCAGACT
T Q L G G E E E E A N T S R T L L E D K D V S V Y S 494
1541 ACTCAGCTGGGAGAAGAAGAGCTAATACCTCCAGGACACTTCTAGAGGATAAGGATGTCTCAGTTGTCTACTC
E V K T Q H P D N S A G K I S S K D E E S * 515
1618 TGAGGTAAGACACAACACCCAGATAACTCAGCTGGAAGATCAGCTCTAAGGATGAAGAAGTTAAGAGAATGAAA
1695 AGTTACGGGAACGTCCTACTCATGTGATTTCTCCCTTGTCCAAAGTCCCAGGCCAGTGCACTCCTTGGCGCACCTG
1772 GAATGATCAACTATTCCAGCTTTCTAATTCTTCTCATGCAATATGCATTCACTCCAGGAATACTCATTCTGCTACT
1849 CTGATGTTGGGATGGAATGGCCTCTGAAAGACTTCACTAAAATGACAGGATCCACAGTTAAGAGAAGACCTGTAG
1926 TATTTGCTGTGGGCTGACCTAATGCATTCCCTAGGGTCTGCTTTAGAGAAGGGGATAAAGAGAGAGAAGGACTGT
2003 TATGAAAAACAGAAGCACAATTTTGGTGAATTGGGATTTGCAGAGATGAAAAAGACTGGGTGACCTGGATCTCTGC
2080 TTAATACATCTACAACCATGTCTCACTGGAGACTCACTTGCATCAGTTTGTAACTGTGAGTGGCTGCACAGGCA
2157 CTGTGCAAAACATGAAAGCCCTTCACTTCTGCTGCACAGCTTACACTGTGAGGATTCAGTTGCAGATTAAGAA
2234 CCCATCTGGAATGGTTTACAGAGAGAGGAATTTAAAGAGGACATCAGAAGAGCTGAGATGCAAGCTCTAGGCTGC
2311 GCTTCCAAAAGCAATGATAATTATGTTAATGTCAATAGTGACAAAGATTGCAACATTAGAGAAAAGAGACACAAA
2388 TATAAAATTAAGTACCAACTCTCCAAACTAAATTTGAACCTAAATATTAGTATAAACTCATATAATAA
CTCTGCTTTTAAATAAAAA

IRTA1 cDNA and protein sequence

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FIGURE 18B-1

IRTA2A
IRTA2C
IRTA2B 1

CGGTGCAGTGTCTGACTGTAAGATCAAGTCCAAACCTGTTTGGGAATTGAGGAAACTTCTCTTTTGATCTCAGCCCTTG
H L L W V I L L V L A P V S G V Q F A R T P R
81 GTGGTCCAGGTCTTCATGCTGCTGTGGGTGATATTACTGGTCTGGCTCTGTCAGTGGACAGTTTGAAGGACACCCAG 22
P I I F L Q P P W T T V F Q G E R V T L T C K G F R F
161 GCCCATTATTTCTCCAGCTCCATGGACCACAGTCTTCCAAGGAGAGAGAGTGAACCTCACTTGAAGGGATTTCGCT 49
Y S P Q K T K W Y H R Y L G K E I L R E T P D N I L
241 TCTACTCACCACAGAAAACAAATGGTACCATCGGTACCTTGGGAAAGAAATACTAAGAGAAACCCAGACAATATCCTT 75
E V Q E S G E Y R C Q A Q G S P L S S P V H L D F S S
321 GAGGTCAGGAATCTGGAGAGTACAGATGCCAGGCCAGGGCTCCCTCTCAGTAGCCCTGTGCACTTGGATTTCCTTC 102
A S L I L Q A P L S V F E G D S V V L R C R A K A E V
401 AGCTTCGCTGATCTGCAAGCTCCACTTTCTGTGTTTGAAGGAGACTCTGTGGTCTGAGGTGCCGGGCAAGCGGAAG 129
T L I Y K N D N V L A F L N K R T D F H I P H
481 TAACCTGATTAATCTATTACAAGAATGATAATGCTGGCATTCTTAATAAAGAACTGACTTCCATATTCCTCAT 155
A C L K D N G A Y R C T G Y K E S C C P V S S N T V K
561 GCATGCTCAAGGACAATGGTGCATATCGCTGTACTGGATATAAGGAAAGTGTGTGCCCTGTTCCTTCAATACAGTCAA 182
I Q V Q E P F T R P V L R A S S F Q P I S G N P V T L
641 AATCCAAGTCCAAGAGCCATTTACAGTCCAGTCTGAGAGCCAGTCTTCCAGCCCATCAGCGGAACCCAGTGACCC 209
T C E T Q L S L E R S D V P L R F R F R D D Q T L
721 TGACCTGTGAGACCCAGCTCTCTCTAGAGAGGTGATGTCCTCCGCTCCGCTTCTTCCAGAGATGACCCAGCCCTG 235
G L G W S L S P N F Q I T A M W S K D S G F Y W C K A
801 GGATTAGGCTGGAGTCTCTCCCGAATTTCAGATTACTGCCATGTGGAGTAAAGATTCCAGGGTCTACTGGTGAAGGC 262
A T M P H S V I S D S P R S W I Q V Q I P A S H P V L
881 AGCAACAATGCCTCAGAGCTCATATCTGACAGCCGAGATCTGGATACAGGTGCAGATCCCTGCATCTCATCTGTCTC 289
T L S P E K A L N F E G T K V T L H C E T Q E D S L
961 TCACCTCAGCCCTGAAAAGGCTCTGAATTTTGAAGGAACCAAGGTGACACTTCACTGTGAACCCAGGAAGATTCTCTG 315
R T L Y R F Y H E G V P L R H K S V R C E R G A S I S
1041 CGCACTTTGTACAGGTTTATCATGAGGGTGTCCCGTGAGGCACAAGTCAGTCCGCTGTGAAGGGGAGCATCCATCAG 342
F S L T T E N S G N Y Y C T A D N G L G A K P S K A V
1121 CTTCTCACTGACTACAGAGAATTCCAGGAATCTACTGCACAGCTGACAATGGCTTGGCGCCCAAGCCAGTAAGGCTG 369
S L S V T V P V S H P V L S P E D L I F E G A
1201 TGAGCCTCTCAGTCACTGTTCCTGCTCTCCTGCTCTCCTGAGGACCTGATTTTGAAGGAGCC 395
K V T L H C E A Q R G S L P I L Y Q F H H E D A A L E
1281 AAGGTGACACTTCACTGTGAAGCCAGAGAGGTTCACCTCCCATCTGTACCAGTTTCATCATGAGGATGTCGCCCTGGA 422
R R S A N S A G G V A I S F S L T A E H S G N Y Y C T
1361 GCGTAGCTCGGCCAACTCTGCAGGAGGAGTGGCCATCAGCTTCTCTGACTGCAGAGCATTAGGGAATCTACTGCA 449
A D N G F G P Q R S K A V S L S I T V P V S H P V L
1441 CAGCTGACAATGGCTTTGGCCCCCAGCCAGTAAGGGGGTGGAGCTTCCATCACTGTCCCTGTGTCTCATCTGTCTCTC 475
T L S S A E A L T F E G A T V T L H C E V Q R G S P Q
1521 ACCCTCAGCTCTGCTGAGGCCCTGACTTTTGAAGGAGCCACTGTGACACTTCACTGTGAAGTCCAGAGGTTCCCAACA 502
I L Y Q F Y H E D M P L W S S S T P S V G R V S F S F
1601 AATCTTATACAGTTTATCATGAGGACATGCCCTGTGGAGCAGTCAACACCCCTCTGTGGGAAGAGTGTCTTCAGCT 529
S L T E G H S G N Y Y C T A D N G F G P Q R S E V V
1681 TCTCTGACTGAAGGACATTACAGGAATTACTACTGCACAGCTGACAATGGCTTTGGTCCCCAGCCAGTGAAGTGGTG 555
S L F V T V P V S R P I L T L R V P R A Q A V V G D L
2A, 2C1761 AGCCCTTTTGTCACTGTTCAGTGTCTCGCCCATCTCACCCTCAGGGTTCCAGGGCCAGGCTGTGGTGGGGGACCT 582
G K C W V L A S H P P L A E F S L T H S F K
2B 1761 -----GGTAAGTGTGGGTCTTGCCAGTCAACCCCTGGCTGAGTTCTCTCTACCCATTCTTTAA 582
L E L H C E A P R G S P P I L Y W F Y H E D V T L G S
2A, 2C1841 CCGTGGAGCTTCACTGTGAGGCCCGAGAGGCTCTCCCCAATCCTGTACTGGTTTATCATGAGGATGTACCCCTGGGGA 609
N L F A L S S P L P * stop
2B 1841 AATCTGTTTCACTGTCCAGTTTCTCCCTAATCAACTTAATCCCTTCTTGGCTTCTCTCAACTAACTAGCTGGG 592
S S A P S G G E A S F L T A E H S G V Y Q C E
2A, 2C1921 GCAGCTCAGCCCCCTCTGGAGGAGAAGCTTCTTCAACTCTCTGACTGCAGAACATTCTGGAATCTCATGTGAG 635
2B 1921 GTTTCCGTACTCATAAGTCTGGCTCAGCCAGACCCCTAAAACAGCTCAGTAGATTCCCCAGCTTTTACCAATGAATT
A N N G L V A Q H S D T I S L S V I V P V S R P I L T
2A, 2C2001 GCCAACAATGGCTAGTGGCCAGCAGTGCACAAATACACTCAGTGTATAGTTCAGTATCTCGTCCCATCTCTAC 662
2B 2001 TATTATTGTATTTCTCTCATCTCTGATGTTCCAAACAGTACGCCAATTTTCTTGATGACCGAGGCTGTCTACT
F R A P R A Q A V V G D L L E L H C E A L R G S S P I
2A, 2C2081 CTTCAGGCTCCAGGGCCAGGCTGTGGTGGGGACCTGCTGGAGCTTCACTGTGAGGCCCTGAGAGGCTCTCTCCCAA 689
2B 2081 TCTCTACTGACATTACATATTAATCTAGCTACAAGCAGAGTCTTAGATAAATATTGGTCAAGACCTTAAATCTCCA

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FIGURE 18B-2

LYWFYHEDVTLGKISAPSGGGASF 715
2A, 2C2161 TCCTGTACTGGTTTATCATGAAGATGTCACCCCTGGTAAGATCTCAGCCCCCTCTGGAGGAGGGGCTCCTTCAGCTC
2B 2161 AAGGATTTCCAATCTTATGGTAGATTGGAGAAAGCTGCTGGTGAACAAAGGGGAAATGGCTCCCTAGGAACCAACTCC

LTTEHSGIYSCEADNGLAQRSEMT 742
2A, 2C2241 TCTCTGACTACAGAACATTCTGGAATCTACTCCTGTGAGGAGAGCAATGGTCTGGAGGCCAGCGCAGTCAGATGGTGAC
2B 2241 TCAAACCTCTGGAGTTTTATGATCCCTGTTTCTAACCTGCTAAAATCAGTATCATTATTTATGTTATTTAAAAA

LKVAVPVSRPVLTLRAPGTHAAVGDLL 769
2C 2321 ACTGAAAGTTGCAGTTCCGGTGTCTCGCCGGTCTCACCCTCAGGGCTCCCGGGACCCATGCTGCGGTGGGGGACCTGC
-----GEWALPTSSSEN*
2A 2321 -----GGTGAGTGGGCTCGCCAGGAGCAGTCTGAGAACTGACTGTGCTGTCTCCCTGCAGCTGA 759
2B 2321 ACTATGTTGAAGTATGACATACATTCAAGAAACGTGCAAAATTGTATGTGTACGATTGGTGTCTTTTAGGAGCTAA

ELHCEALRGSPILLYRFFHEDVTLG 795
2C 2401 TGGAGCTTCACTGTGAGGCCCTGAGAGGCTCTCCCTGATCTGTACCGGTTTTTTCATGAGGATGTCACCCTAGGAAT
2A 2401 AAATGGAGCCACAGAGCTCCTCAGGGCTGTTTGTCTGTGTGGCATCCAGCACACTCTCTGCTGCAGAACCTCCCTGTG
2B 2401 GTTGCTCTGTTTTACTTGAATCTTTGTTTATAGAACTGGGGGAAAGTTACTTTCTTTTCAGAGAAGCCAAATGGTA

SPSGGASL LTAEHSG CEAD 822
2C 2481 AGGTCGTCCTCCCTCTGGAGGAGCGTCTTAACCTCTCTGACTGCAGAGCACTCTGGAACCTACTCTGTGAGGCCGA
2A 2481 AAAGTCTCGGATCCTTTGTGGTATGGTTCAGGAATCTGATGTTCCAGCAGCTCTCTTGAAGATGATCAAGCACTC
2B 2481 TGATAGAAAATCTTGAGCCTGATGTGTGTCAGACATGCCCCAGCATAACTGTTGAGTAAAGAGGTTATTTTAAATGT

NGLGARQRETVTLYITGLTA GPFA 849
2C 2561 CAATGGCTCGGGGCCAGCGCAGTGAGACAGTACACTTTATATCACAGGGCTGACCGCGAACAGAGACTGGCCCTTTTG
2A 2561 ACTAAAATGCAATAAGACTTTTATAGAACATAAATATATCTGAACTGAAATATTACATGAAAATGAAACCAAGA
2B 2561 GAATGTTCTGAGACTACTCAAAGTCAGAGCCAAATCTACTAGGAAGCTTCTAGACTTCATCATCTGCAATCCCATTA

TGVAGGLLSIAGLAAAGALLLYCWL SR 875
2C 2641 CCACAGGAGTCCGCGGGGCTGCTCAGCATAGCAGGCTGTGCTGCGGGGCACTGCTGCTACTGCTGGCTCTCGAGA
2A 2641 ATCTGAGCATATGTTTCTCTGCGGTAGAAAGGATTAAGCTGTTTCTGTGCGGATCTCTCTCATGACTCTTAAGAA
2B 2641 TATCTTTTATCCATGTTTACTTTCTCTCATATTCAGCAGCATCTTAAGCCTCTTTATTTTCTGTTTCTGACTGTCA

KAGRKPA SDPARSPSDSDSQEPTYHN V 902
2C 2721 AAAGCAGGAGAAAGCCTGCTCTGACCCCGCAGGAGCCCTTCAGACTCGGACTCCCAAGAGCCCACTATCAAAATG
2A 2721 GCCTCTACTCTTGAGTCTCTTTCAATTAAGGATGTAATGTTTCTTACATTTCCACATTAATAATCTATGTTAACGA
2B 2721 CCCTTAATGCCAGTAGAATGTAAGCTTCATGAGAACAGAACTGCATCCATCTTGGTCTTCAACATCCCTGTGCTACT

PAWEEELQPVYTNA NPRGENVVVYSEVRI 929
2C 2801 ACCAGCCTGGGAGAGCTGCAACAGGTGTACATAATGCAAACTTAGAGGAGAAAATGTGGTTTACTCAGAAGTACGGA
2A 2801 AAAAA
2B 2801 CAGTGTGGCACACAGTAGGTCTCAGTCAACATTGTAAATTTAGTGGACAGATGATATGACAAGATGATAAGAGGGGA

IQEKKKHAVA SDPRHLRNKGSPIIYSE 955
2C 2881 TCATCAAGAGAAAAGAAACATGAGTGGCTCTGACCCAGGCATCTCAGGAACAAGGGTTCCCTATCATCTACTCT
2B 2881 TTTAAAAAATCATCTAGCAAGCCCAAGAGGAAAAAACAAGCTATTTAGAAATGAAATACCAATTTGAAGCAGTA

EVKVASTPVSGSLFLASSAPHR * stop 977
2C 2961 GAAGTTAAGGTGGCGTCAACCCCGGTTTCCGGATCCCTGTTCTTGGCTTCTCAGCTCTCAGATGAGTCCACACGTC
2B 2961 AGAATAGATTGGATATCTTTGAAAACCAATTAATGAATGAAGAACCAATTTGAGAAAACAATACAGAAATGCAAGTAGAA

3041 TCTCCAACCTGCTGTTTCAGCCTCTGACCCCAAGTTCCCTTGGGGGAGAAGCAGCATTGAAGTGGGAAGATTAGGCT
2B 3041 AGATACAGAAATAAAGGCAAAAGTTATAATATGGAATCAGACAATGGATTGTCTGTATCCAGTTATGTGGATAATTAA

3121 GCCCCAGACCATATCTACTGGCCTTTGTTTACATGTCTCTCATTCTCAGTCTGACCAGAAATGCAGGGCCCTGCTGGACTG
2B 3121 AATGGAGACCCCTCAGAAAATGAAACCGAAGAGTAAATGAACTCAAAAATGTAGTAGAAATTTGTGGGAAGTAAAGAAA

3201 TCACCTGTTTCCAGTTAAAGCCCTGACTGGCAGGTTTTTTAATCCAGTGGCAAGGTGCTCCCACTCCAGGGCCCGACAC
2B 3201 ACTTGAATATGTAGATCAGAACATATATGTTGATGACGTTATTGACTTTGAGGTTAAAAATATATATATGTGCTATGAT

3281 ATCTCTGGAATCTCTAGTGGGCTTCACTGTGCTGCTGTTCTGAGTACTGCTCTCATCACACCCCCACAGAGGGGGTC
2B 3281 TATGGGAAAAAAGCAGTCGCTCAGAAAAGAAAACATCAAGTTAGTCTTAGACTTTGACGTGCACTCAGTACCAAGAGAG

3361 TTACCACAAAAGGAGAGTGGGCTTCAGGAGATGCCGGCTGGCCTAACAGCTCAGGTGCTCTTAACTCCGACACAG
3441 AGTTCTCTGCTTTGGGTGGATGCAATTCTCAATTTGTCTATCAGCCTGGTGGGGCTACTGCACTGTGCTGCCAAATGGGACAG
3521 CACACAGCCTGTGCATGAGGACATGTATGGGTCTCCCAAGGGGGCTGCAATTTCACTCTCTCCCTGCTCTCAAACT
3601 CTAAGGTCGGCACTTGACACCAAGGTAACCTTCTCTCTGCTCATGTGTGCTGCTTACCTGCCCAAGTAAAGTGGCTTCA
3681 TACACCAAGTCCCGAAGTTCTTCCATCTTAACAGAAATACCCAGCAAGTCAAGGCCAGGAGGACAGGGGTGCAGACA
3761 GAACACATACTGGAACACAGGAGGTGCTCAATTAATTTGACTGACTGACTGAATGAATGAATGAATGAGGAAGAAAAC
3841 TGTGGGTAATCAAACTGGCATAAAATCCAGTGCACCTCCTAGGAAATCCGGGAGGTATTCTGGCTCTTAAGAAAACAG
3921 GAAGAGAAAGGAGCTTGGATGAAGAACTGTTCAAGAAAGAGGGCTTCTTCACTTTTATGTGCTTGTGGATCACCT
4001 GAGGATCTGTGAAAATACAGATACTGATTCACTGGGTCTGTGTAGAGCCTGAGACTGCCATTCTAACATGTTCCAGGGG

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FIGURE 18B-3

4081 ATGCTGATGCTGCTGGCCCTGGGACTGCACTGCATGTCATGTGAAGCCCTATAGGTCTCAGCAGAGGGCCCATGGAGAGGGA
4161 ATGTGTGGCTCTGGCTGCCAGGGCCCAACTCGGTTACACGGATCGTGTGCTCCCTGGCCAGCCTTTGGCCACAGCAC
4241 CACCAGCTGCTGTGTGCTGAGAGAGCTTCTTCTGTGACATGTTGGCTTTCATCAGCCACCCTGGGAAGCGGAAAGTAGC
4321 TGCCACTATCTTTGTTTCCCACCTCAGGCCTCACACTTCCCATGAAAAGGGTGAATGTATATAACCTGAGCCCTCTCC
4401 ATTACAGATTGTTCTCCCATCTCTGAGCAATGGGATGTTCTGTTCCGCTTTTATGATATCCATCACATCTTATCTTGATC
4481 TTTGCTCCAGTGGATTGTACAGTGATGACTTTTAAGCCCCACGGCCCTGAAATAAAATCCTTCCAAGGGCATGGGAAGC
4561 TCACTCCACCTGAACCATGGCTTTTCATGCTTCCAAGTGTCAAGGCCTTGCCAGATAGACAGGGCTGACTCTGCTGCC
4641 CAACCTTTCAAGGAGGAAACCAGACACCTGAGACAGGAGCCTGTATGCAGCCAGTGCAGCCTTGCAAGGACAAGGCTG
4721 GAGGCATTTGTCACTACAGATATGCAACTAAAAATAGACGTGGAGCAAGAGAAATGCATTCCCACCGAGGCCGCTTTT
4801 TTAGGCCTAGTTGAAAGTCAAGAAGGACAGCAGCAAGCATAGGCTCAGGATTAAAGAAAAAATCTGCTCACAGTCTGTT
4881 CTGGAGGTCACATCAACAAAGCTCAGCCCTATGCAGTTCTGAGAAGGTGGAGGCACAGGCTCAAAAGAGGAAATT
4961 TAGAATTTCTCATTGGGAGAGTAAGGTACCCCATCCAGAATGATAACTGCACAGTGGCAGAACAACTCCACCCTAAT
5041 GTGGGTGGACCCCATCCAGTCTGTTGAAGGCCTGAATGTAAACAAAAGGGCTTATTCTTCTCAAGTAAGGGGGAACCTCT
5121 GCTTTGGGCTGGGACATAAGTTTTCTGCTTTCAGACGCAAACTGAAAAATGGCTCTTCTTGGGTCTTGAGCTTGCTGGC
5201 ATATGGACTGAAAGAACTATGCTATTGGATCTCTGGATCTCCAGCTTGCTGACTGCAGATCTTGAGATATGTCAGCCT
5281 CTACAGTCACAAGAGCTAATTCATTCTAATAAACCAATCTTTC

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FIGURE 18C-1

1 AGTGAAGGGGTTTCCCATATGAAAAATACAGAAAGAATTATTTGAATACTA
52 GCAAATACACAACCTTGATATTTCTAGAGAACCCAGGCACAGCTCTGGAGAC
103 ATTACTCCTGAGAGACTGCAGCTGTAGGAAGATGAGCCCCAACTTCTAAAA
154 ATGTATCACTACCGGGATTGAGATACAAACAGCATTTAGGAAGGTCTCATC
205 TGAGTAGCAGCTTCTGCGCTCTTCTTGGAGATAAGTCGGGCTTTTGGTG
256 AGACAGACTTTCCCAACCTCTGCCCCGGCGGTGCCCATGCTTCTGTGGCT
1 M L L W L
307 GCTGCTGCTGATCTGACTCTGGAAGAGAACATCAGGGGTGGCCCCAAA
6 L L L I L T P G R E Q S G V A P K
358 AGCTGTACTTCTCTCAATCTCCATGGTCCACAGCCTTCAAAGGAGAAAA
23 A V L L L N P P W S T A F K G E K
409 AGTGGCTCTCATATGNCAGCAGCATATCATTCCCTAGCCCAGGGAGACAC
40 V A L I C S S I S H S L A Q G D T
460 ATATTGGTATCAGATGAGAAGTTGTTGAAAAATAAACATGACAAGATCCA
57 Y W Y H D E K L L K I K H D K I Q
511 AATTACAGAGCCTGGAATTACCAATGTAAGACCCGAGGATCTCTCCCTCAG
74 I T E P G N Y Q C K T R G S S L S
562 TGATGCGTGCATGTGGAATTTTCACTGACTGGCTGATCTCGAGGCTTT
91 D A V H V E F S P D W L I L Q A L
613 ACATCCTGTCTTTGAAGGAGACAATGTCATTCTGAGATGTGAGGGGAAAGA
108 H P V F E G D N V I L R C Q G K D
664 CAACAAAAACACTCATCAAAAGTTTACTACAAGGATGGAACAGCTTCC
125 N K N T H Q K V Y Y K D G K Q L P
715 TAATAGTTATAATTAGAGAAGATCAGTGAATTCACTCTCCAGGATAA
142 N S Y N L E K I T V N S V S R D N
766 TAGCAATATCATTGTACTGCTTATAGGAAGTTTACATACTTGACATTGA
159 S K Y H C T A Y R K F Y I L D I E
817 AGTAACTTCAAACCCCTAAATATCCAAGTTCAAGAGCTGTTTCTACATCC
176 V T S K P L N I Q V Q E L F L H P
868 TGTGCTGAGAGCCAGCTCTTCCACGCCCATAGAGGGGAGTCCCATGACCT
193 V L R A S S S T P I E G S P M T L
919 GACCTGTGAGACCCAGCTCTTCCACAGAGGCCAGATGTCCAGCTGCAAT
210 T C E T Q L S P Q R P D V Q L Q F
970 CTCCCTCTTCAGAGATAGCCAGACCTCGGATGGGCTGGAGCAGGTCCCC
227 S L F R D S Q T L G L G W S R S P
1021 CAGACTCCAGATCCCTGCCATGTGGACTGAAGACTCAGGGTCTTACTGGTG
244 R L Q I P A M W T E D S G S Y W C
1072 TGAGGTGGAGACAGTCACTCAGCATCAAAAAAGGAGCCTGAGATCTCA
261 E V E T V T H S I K K R S L R S Q
1123 GATACGTGTACAGAGAGTCCCTGTGTCTAATGTGAATCTAGAGATCCGGCC
278 I R V Q R V P V S N V N L E I R P
1174 CACCGGAGGGCAGCTGATTGAAGGAGAAATATGGTCTTATTGTCTCAGT
295 T G G Q L I E G E N M V L I C S V
1225 AGCCCCAGGGTTCAGGGACTGTACATTCTCTGGCACAAAGAAGGAAGAGT
312 A A Q G S G T V T F S W H K E G R V
1276 AAGAAGCCTGGGTAGAAAGACCCAGCGTTCCCTGTTGGCAGAGCTGCATGT
329 R S L G R K T Q R S L L A E L H V
1327 TCTCACCCTGAAGGAGAGTGTGACAGGGAGATACTACTGTGACAGTGATAA
346 L T V K E S D A G R Y Y C A A D N
1378 CGTTCACAGCCCCATCTCAGCAGCTGGATTGAGTCACCGTGAGAATTC
363 V H S P I L S T W I R V T V R I P
1429 GGTATCTCACCTGTCTCACCTTCAGGGCTCCAGGGGCCACACTGTGGT
380 V S H P V L T F R A P R A H T V V
1480 GGGGGACCTGCTGGAGCTTCACTGTGAGTCCCTGAGAGGCTCTCCCCGAT
397 G D L L E L H C E S L R G S P P I
1531 CCTGTACCGATTTTATCATGAGGATGTACCCCTGGGGAACAGCTCAGCCCC
414 L Y R F Y H E D V T L G N S S A P
1582 CTCTGGAGGAGGAGCTCTTCAACCTCTCTGACTGCAGAACATTCTGG
431 S G G G A S F N L S L T A E H S G
1633 AAATACTCCTGTGATGCAGACAATGGCCTGGGGGCCAGCACAGTCATGG
448 N Y S C D A D N G L G A Q H S H G
1684 AGTGAGTCTCAGGGTCAGATTCGGGTGTCTGCCCCGCTCTCACCTCAG
465 V S L R V T V P V S R P V L T L R
1735 GGCTCCCCGGGGCCAGGCTGTGGTGGGGGACCTGCTGGAGCTTCACTGTGA
483 A P G A Q A V V G D L L E L H C E
1786 GTCCCTGAGAGGCTCTTCCCGATCTGTACTGGTTTATCAGGAGGATGA
499 S L R G S F P I L Y W F Y H E D D
1837 CACCTTGGGGAACATCTCGGCCACTCTGGAGGAGGGGATCTTCAACCT
516 T L G N I S A H S G G G A S F N L
1888 CTCTCTGACTACAGAACATTCTGGAACACTCATGTGAGGCTGACAATGG
533 S L T T E H S G N Y S C E A D N G

FIGURE 18C-2

1939 CTTGGGGGCCCCAGCACAGTAAAGTGGTGACACTCAATGTTACAGGAACCTTC
550 L G A Q H S K V T L N V T G T S
1990 CAGGAACAAGAAGCGCCTTACCAGCTGCGGGAATACAGGGGCTGGTGCTCAG
567 R N R T G L T A A G I T G L V L S
2041 CATCTCGTCTGCTGCTGCTGCTGCTGCTGCTGCATTACGCCAGGGCCCCG
584 I L V L A A A L L H Y A R A R
2092 AAGGAAACCAGGAGGACTTCTGCCACTGGAACATCTAGTCACAGTCTTAG
601 R K P G G L S A T G T S S H S P S
2143 TGAGTGTCAAGAGCTTCTCTCGTCCAGGCTTCCAGGATAGACCTCAAGA
618 E C Q G E F S S S R P S R I D P Q E
2194 GCCCACTCATCTAAACCATAGCCCAAATGGAGCTGGAGCCAATGTACAG
635 P T H S K P L A P M E L E P M Y S
2245 CAATGTAAATCCTGGAGATAGCAACCCGATTATTCCAGCATCTGGAGCAT
652 N V N P G D S N P I Y S Q I W S I
2296 CCAGCATACAAAAGAAACCTACGCTAATTGTCCAAATGCATGCATCAAGAGCA
669 Q H T K E N S A N C P M M H Q E H
2347 TGAGGAACCTACAGTCTCTTATTACAGAACTGAAGAGACACACCCAGACGA
686 E E L T V L Y S E L K K T H P D D
2398 CTCTGCAGGGGAGGCTAGCAGCAGAGGCAGGGCCCATGAAGAAGATGATGA
703 S A G E A S S R G R A H E E D D E
2449 AGAAAACTATGAGATGTACCACTGATTAATTCGGCTCAGACCACTAGCC
720 E N Y E N V P R V L C S D H
2500 CCTTACCCAGAGTGCCCCACAGGAACAGCCTGCACCAATTTTTTTTCTGT
2551 TCTCTCAACACACATCATCATCTCTCCAGACTCTGCTCTCTACGAGGC
2602 TGGCTGTCAGGGTATGTGAGGCTGAGCAAAAGGCTCTGCAAAATCTCCCCTGT
2653 CGCTGATCTGTGTGTTCCCCAGGAAGAGAGCAGGCAGCCTCTGAGCAAGCA
2704 CTGTGTTATTTTCAGATGGAGACAGCTGGCAAGGCAGGAGGCCCTCAGGC
2755 TCCTAGGGCTCTGCAATATGAGGAGAGAGAGAAATGCTCTAGCCAGGGTTA
2805 CAAGGGCAACATCATGACCATTGTATCAAGATGTGATCGAAAGCTGTTAAT
2857 GTGCTCTCTGTATAAACAAATTGCTCCAAATTTGTTTCCCTTTTGT
2908 GTGGCTGTGATGGCATTGCTGATGTTTGGTGTAATATGCTGTATCTTGC
2959 TACCATTATGGG

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FIGURE 18D-1

1 TGGTGACCAAGAGTACATCTCTTTTCAAATAGCTGGATTAGGTCCTCATGC
1 M L
52 TGCTGTGGTCATTGCTGGTCATCTTTGATGCAGTCACTGAACAGGCAGATT
19 L W S L L V I F D A V T E Q A D S
103 CGCTGACCCCTTGTGGCGCCCTCTTCTGTCTTCAAGGAGACAGCATCGTTC
36 L T L V A P S S V F E G D S I V L
154 TGAATGCCAGGGAGAACAGAACTGGAAAATTCAGAAGATGGCTTACCATA
53 K C Q G E Q N W K I Q K M A Y H K
205 AGGATAACAAAGAGTTATCTGTTTCAAAAAATTCAGATTTCTTATCC
70 D N K E L S V F K K F S D F L I Q
256 AAAAGTGCAGTTTAAAGTGACAGTGGTAACTATTTCTGTAGTACCAAAGGAC
87 S A V L S D S G N Y F C S T K G Q
307 AACTCTTTCTCTGGGATAAACTTCAAATATAGTAAAGATAAAAGTCCAAG
104 L F L W D K T S N I V K I K V Q E
358 AGCTCTTTCAACGTCCTGTGCTGACTGCCAGCTCCTTCCAGCCCATCGAAG
121 L F Q R P V L T A S S F Q P I E G
409 GGGGTCCAGTGAGCCTGAAATGTGAGACCCGGCTCTCTCCACAGAGGTGG
138 G P V S L K C E T R L S P Q R L D
460 ATGTTCAACTCCAGTTCTGCTTCTTCAAGAGAAAACAGGTCCTGGGGTCAG
155 V Q L Q F C F F R E N Q V L G S G
511 GCTGGAGCAGCTCTCCGGAGCTCCAGATTTCTGCCGTGTGGAGTGAAGACA
172 W S S S P E L Q I S A V W S E D T
562 CAGGCTTACTGGTGCAAGGCAGAAACGGTGACTCACAGGATCAGAAAAC
189 G S Y W C K A E T V T H R I R K Q
613 AGAGCCCTCAATCCAGATTCACGTGCAGTGAATCCCATCTCTAATGTAA
206 S L Q S Q I H V Q R I P I S N V S
664 GCTTGGAGATCCGGGCCCCGGGGGACAGGTGACTGAAGGACAAAACTGA
223 L E I R A P G G Q V T E G Q K L I
715 TCCTGCTCTGCTCAGTGGCTGGGGGTACAGGAAATGTACATTCTCCTGGT
240 L L C S V A G G T G N V T F S W Y
766 ACAGAGAGGCCACAGGAACCACTATGGGAAAGAAAACCCAGCGTTCCCTGT
257 R E A T G T S M G K K T Q R S L S
817 CAGCAGAGCTGGAGATCCAGCTGTGAAGAGAGTGTGCGGCAAAATATT
274 A E L E I P A V K E S D A G K Y Y
868 ACTGTAGAGCTGACAACGGCCATGTGCCTATCCAGAGCAAGGTGGTGAATA
291 C R A D N G H V P I Q S K V V N I
919 TCCCTGTGAGAATTCCAGTGTCTCGCCCTGTCTCACCTCAGGTCTCCTG
308 P V R I P V S R P V L T L R S P G
970 GGGCCAGGCTGCAGTGGGGGACCTGCTGGAGCTTCACTGTGAGGCCCTGA
325 A Q A A V G D L L E L H C E A L R
1021 GAGGCTCTCCCCAATCTTGTAACCAATTTATCATGAGGATGTCAACCCTG
342 G S P P I L Y Q F Y H E D V T L G
1072 GGAACAGCTCGGCCCTCTGAGGAGGGGCTCCTTCAACCTCTCTTTGA
359 N S S A P S G G G A S P N L S L T
1123 CTGCAGAACATTCTGGAACACTACTCTGTGAGGCCAACCAACGGCTGGGGG
376 A E H S G N Y S C E A N N G L G A
1174 CCCAGTGCAAGGAGGAGTCCAGTCTCCATCTCAGGACCTGATGGCTATA
393 Q C S E A V P V S I S G P D G Y R
1225 GAAGAGACCTCATGACAGCTGGAGTTCTCTGGGGACTGTTGGTGTCTTG
410 R D L M T A G V L W G L F G V L G
1276 GTTTCAGTGGTGTGCTTTGCTGTGTATGCTTGTCCACAAGATATCAG
427 F T G V A L L L Y A L F H K I S G
1327 GAGAAAGTTCTGCCACTAATGAACCCAGAGGGGCTTCCAGGCCAAATCCTC
444 E S S A T N E P R G A S R P N P Q
1378 AAGAGTTCACCTATTCAAGCCCAACCCAGACATGGAGGAGCTGCAGCCAG
461 E F T Y S S P T P D M E E L Q P V
1429 TGTATGTCAATGTGGCTCTGTAGATGTGGATGTGGTTATTCTCAGGTCT
478 Y V N V G S V D V D V V Y S Q V W
1480 GGAGCATGCAGCAGCCAGAAAGCTCAGCAAACATCAGGACACTTCTGGAGA
495 S M Q Q P E S S A N I R T L L E N
1531 ACAAGGACTCCCAAGTCATCTACTCTTCTGTGAAGAAATCATAACACTTGG
512 K D S Q V I Y S S V K K S
1582 AGGAATCAGAAAGGAGATCAACAGCAAGGATGGGGCATCATTAAGACTTG
1633 CTATAAACCTTATGAAATGCTTGAGGCTTATCACTGCCACAGCCAGAA
1684 CGTGCTCAGGAGGCCACCTCTGTGCTATTTTGTCTGATGATGTTCTTCT
1735 CCAATATCTTCTTTACCTATCAATATTCAATGAAGTGTGTACATCCAG
1786 ACACTGTGCAAATAAATTTTCTGCTACCTTCTCTTAAGCAATCAGTGTG
1837 TAAAGATTTGAGGGAAGATGAATAAGAGATACAAGGTCTCACCTTCACT
1888 ACTGTGAAGTGTAGAGAACAGGACTTGATAGTGGTGATTAACTTATTAT
1939 GTGCTGTGGATACAGTTTGCTAATATTTTGTGAGAAATTTTGCAATAT

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FIGURE 18D-2

1990 GTTCATTGGGAATATTGGCCTGAAATTTTCTTTTCCACTGTGCTCTGCCA
2041 GAATGTTTGTATCAGGCTGATGCTGGCTTCATAGAATGAGTTAGGCAGGAG
2092 CCCTTCCTCCTTGATTTTTTGGCATAGTTTCAGCAGGATTGGTACCAGTTA
2143 TTCTTTCTGCATCTTGTAAGAATTCAGCTATGAATCCATCTGGTCTAGGGCT
2194 TTTGTGTTGGTTGGTAAGTTTTTTATTACTAATTCAACTTCAGCGCTTGAT
2245 ATTGGTCTAGGAGGGGTTTCTGTCTCTTCCTGGTTCAATCTTGGGAGATTG
2296 TGTGTTTCCAGGAATTTAGCCGTTTCCTCCAGATTTTCTTCTTTATGTGCA
2347 TCGACTTGAGTGTAACATAACTTATATGCACTGGGAAACCAAAAAATCTG
2398 TGTGACTTGCTTTATTGCAGCATTGTTTTATTTTGGTAGTCTGGAACTGA
2449 ACCTGCAATATCACCAAGTATGCATATAGTTGCAAAAATGTGATTTTGA
2500 CATAGTAAATATGAGTATTTGCAATAAACTATGATATTACTTTTGTAAAGTA
2551 TATAGAATAAAATGTAATAATCTATAAAA

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FIGURE 18E-1

1 GAGGCATCTCTAGGTACCATCCCTGACCTGGTCCTC
 37 ATGCTGCCGAGGCTGTTGCTGTGATCTGTGCTCCACTCTGTGAA
 M L P R L L L L I C A P L C E
 82 CCTGCCGAGCTGTTTTGATAGCCAGCCCTCCCATCCACAGAG
 P A E L F L I A S P S H P T E
 127 GGGAGCCCACTGACCTGACGTGAAGATGCCCTTTCTACAGAGT
 G S P V T L T C K M P F L Q S
 172 TCAGATGCCAGTTCCAGTTCTGCTTTTTCAGAGACACCCGGGCC
 S D A Q F Q F C F F R D T R A
 217 TTGGGCCCAAGCTGGAGCAGCTCCCCCAAGCTCCAGATCGCTGCC
 L G P G W S S S P K L Q I A A
 262 ATGTGGAAGAAGACACAGGGTCATACTGGTGGAGGCACAGACA
 M W K E D T G S Y W C E A Q T
 307 ATGGCGTCCAAAGTCTTGAGGAGCAGGAGATCCAGATAAATGTG
 M A S K V L R S R R S Q I N V
 352 CACAGGGTCCCTGCTGCTGATGTGAGCTTGGAGACTCAGCCCCA
 H R V P V A D V S L E T Q P P
 397 GGAGGACAGGTGATGGAGGGAGACAGGCTGGTCTCATCTGCTCA
 G G Q V M E G D R L V L I C S
 442 GTTGCTATGGGCACAGGAGACATCACCTTCCTTTGGTACAAAGGG
 V A M G T G D I T F L W Y K G
 487 GCTGTAGGTTTAAACCTTCAGTCAAAGACCCAGCGTTCACTGACA
 A V G L N L Q S K T Q R S L T
 532 GCAGAGTATGAGATTCCTTCAGTGAGGGAGAGTGATGCTGAGCAA
 A E Y E I P S V R E S D A E Q
 577 TATTACTGTGTAGCTGAAAATGGCTATGGTCCCAGCCCCAGTGGG
 Y Y C V A E N G Y G P S P S G
 622 CTGGTGAGCATCACTGTGAGAATCCCGGTGTCTCGCCCCAATCCTC
 L V S I T V R I P V S R P I L
 667 ATGCTCAGGGCTCCAGGGCCAGGCTGCAGTGGAGGATGTGCTG
 M L R A P R A Q A A V E D V L
 712 GAGCTTCACTGTGAGGCCCTGAGAGGCTCTCCTCCAATCCTGTAC
 E L H C E A L R G S P P I L Y
 757 TGGTTTTATCACGAGGATATCACCTGGGGAGCAGGTCCGGCCCCC
 W F Y H E D I T L G S R S A P
 802 TCTGGAGGAGGAGCCTCCTTCAACCTTTCCCTGACTGAAGAACAT
 S G G G A S F N L S L T E E H
 847 TCTGGAATACTCCTGTGAGGCCAACAAATGGCCTGGGGGCCAG
 S G N Y S C E A N N G L G A Q
 892 CGCAGTGAGGCGGTGACACTCAACTTCACAGTGCCTACTGGGGCC
 R S E A V T L N F T V P T G A
 937 AGAAGCAATCATCTTACCTCAGGAGTCATTGAGGGGCTGCTCAGC
 R S N H L T S G V I E G L S
 982 ACCCTTGGTCCAGCCACCGTGGCCTTATTATTTTGCTACGGCCTC
 T L G P A T V A L L F C Y G L
 1027 AAAAGAAAAATAGGAAGCGTTACGCCAGGGATCCACTCAGGAGC
 K R K I G R R S A R D P L R S
 1072 CTTCCAGCCCTCTACCCCAAGAGTTCACCTACCTCAACTCACCT
 L P S P L P Q E F T Y L N S P
 1117 ACCCCAGGGCAGCTACAGCCTATATATGAAAATGTGAATGTTGTA
 T P G Q L Q P I Y E N V N V V
 1162 AGTGGGGATGAGGTTTATTCTAGGCGTACTATAACCAGCCGGAG
 S G D E V Y S L A Y Y N O P E
 1207 CAGGAATCAGTAGCAGCAGAAACCTGGGGACACATATGGAGGAC
 Q E S V A A E T L G T H M E D
 1252 AAGGTTTCCTTAGACATCTATTCCAGGCTGAGGAAAGCAAACATT
 K V S L D I Y S R L R K A N I
 1297 ACAGATGTGACTATGAAGATGCTATGTAA 1326
 T D V D Y E D A M *
 GGT ATGGAAGATT CTGCTCTTTG
 1351 AAAACCATCC ATGACCCCAA GCCTCAGGCC TGATATGTTT TCAGAGATC
 1401 CTGGGGCATT AGCTTTCCAG TATACCTCTT CTGGATGCCA TTCTCCATGG
 1451 CACTATTCCCT TCATCTACTG TGAAGTGAAG TTGGCGCAGC CCTGAAGAAA
 1501 CTACCTAGGA GAACTAATAG ACACAGGAGT GACAGGGACT TTGTTATCAG
 1551 AACCAGATTC CTGCGCGCTC CTTTGAATAAC AGGTCAATTT GTGCTCTTCT
 1601 GTTTACAAGA GGAACAAGA TGGAAATAAAA GAAATTTGGGA TCTTGGGTTG
 1651 GAGGGACAGT GAAGCTTAGA GCACATGAAC TCAAGGTTAG TGACTCTGCA
 1701 GGACTTCACA GAGAGAGCTG TGCCCATCAT TCAGTCCAAG TGCTTTCTCT
 1751 GCCCAGACAG CACAGAACTC CAGCCCCGCT ACTTACATGG ATCATCGAGT
 1801 TTCCACCTAA AATATGATTC TATTTATTTT GAGTCACTGT TACCAAATTA

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FIGURE 18E-2

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1851 GAACTAAAC AAAGTTACAT AAAAAGTTAT TGTGACTCCA CTTAATTTTA
1901 GTGACGTATT TTTGTATATA TAGGCCAACC TATACCACAT CCAAAATTAT
1951 GTATCTATTA CAGCCCCTAG AAGCTTTATA AATACAGTGT GTCTTCTTTT
2001 ATTCACAAA TTTTGAAT CGTGGTAATA TGGTTTGAAT CCTGTATCTT
2051 AATTATTTT TTTTAAAT GAGACAGGGT CTCACCTCTG CACTCAATCT
2101 GGAATGCAGT GGCACAATCT TGCCTCACTG CAACGCCTGC CTCTCAGGCT
2151 CAAGCAAACC TCTCACCTCA GCCTGCTGAG TAGCTGGGAC TACAGGCACA
2201 TGCCACCAA CTTGGCCATT TTTGTCTTA CGTAGAGACA AGATTTCACC
2251 GTTTGCCCA GGCTGGTCTC AAACCTCTGG GCTCAAGCAA TGTATTGAAT
2301 TTT
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